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EVALUATION OF METHODS TO PRODUCE AVIATION TURBINE FUELS FROM SYNTHETIC CRUDE OILS PHASE 2

EXXON RESEARCH AND ENGINEERING COMPANY
GOVERNMENT RESEARCH LABORATORY
LINDEN, NEW JERSEY 07036

MAY 1976

TECHNICAL REPORT AFAPL-TR-75-10 Volume II
FINAL REPORT FOR PERIOD 24 JANUARY 1975 - 24 APRIL 1976

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AIR FORCE AERO PROPULSION LABORATORY
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

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This final report was submitted by Exxon Research and Engineering Company under Contract No. F33615-74-C-2036. The effort was sponsored by the Air Force Aero Propulsion Laboratory, Air Force Systems Command, Wright-Patterson AFB, Ohio under Project 3048, Task 304805 and Work Unit 30480559 with Captain Heidi E. Cron as Project Engineer. Dr. Henry Shaw and Dr. William F. Taylor of Exxon Research and Engineering Company supervised the work.

This report describes the second phase (Phase II) of a study being carried out by Exxon Research and Engineering Company for the United States Air Force. The study is directed at evaluating the current technology for the production of aviation turbine fuels from synthetic crude oils. The scope of the program involves engineering analyses, experimentation, design projections, and considerations of availability and economics. The Phase II technical requirements consist of an experimental determination of the feasibility of the production of specification aircraft turbine fuels from certain synthetic crude oils derived from coal and oil shale.

Many individuals from the Department of Defense, NASA, and Exxon made valuable contributions to this study. The author wishes to acknowledge the helpful advice and encouragement received from the following individuals: Messrs. J. P. Longwell, F. H. Kant, and R. B. Long. Mr. Alvin Skopp and Dr. J. W. Harrison had overall management responsibility for the project.

This report has been reviewed by the Information Office, (ASD/OIP) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

Heidi E. Cron

HEIDI E. CRON, CAPT, USAF
Project Engineer

FOR THE COMMANDER

Arthur V. Churchill

ARTHUR V. CHURCHILL
Chief, Fuels Branch
Fuels and Lubrication Division

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An experimental pilot-plant program is described which has demonstrated that specification JP-4 wide-cut type and Jet A narrow-cut type aviation turbine fuels may be produced from domestic shale oils. Three shale oils and two coal-derived liquids were evaluated in the program, which is the second phase in a three phase overall program. (over)

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The original whole crude samples were assayed and fractionated to yield kerosene-boiling-range feedstocks for catalytic hydrotreatment experiments. Three levels of hydrotreatment severity were investigated, using nickel-molybdenum and cobalt-molybdenum catalysts. Hydrotreated products were fractionated and reblended to yield finished fuels. The experimentally obtained process and analytical information will be used in the third phase of the program to provide a basis for an engineering and economic evaluation of the effect of the use of synthetic crude oil in a refinery processing both petroleum and synthetic crude.

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LIST OF ABBREVIATIONS AND SYMBOLS

ASTM	American Society for Testing Materials
bbl (or B)	Barrel - 42 U. S. gallons
BTU	British Thermal Unit
COED	Char Oil Energy Development Process
D	Calendar Day
EPA	U. S. Environmental Protection Agency
FMC	FMC Corporation
FPC	Federal Power Commission
HRI	Hydrocarbon Research Incorporated
kB/SD	Thousand Barrels per Stream Day
lb	Pound
NPC	National Petroleum Council
OCR	U. S. Office of Coal Research
SCF	Standard Cubic Foot (60°F, 1 Atm.)
SD	Stream Day
Ton (or T)	2000 Pounds
TOSCO	The Oil Shale Company
TPD	Tons Per Day
USBM (or B/M)	U. S. Bureau of Mines
W	Watt

PREFIXES

k	Thousand (kilo)
M	Million (mega)
G	Billion (giga)

SECTION I

SUMMARY

This report describes the Phase II portion of Contract F 33615-74-C-2036 initiated by the Air Force Aero Propulsion Laboratory (AFAPL) with joint AFAPL and NASA support to evaluate the feasibility of producing jet fuel from synthetic crude oils derived from shale oil and coal.

At the conclusion of Phase I of this study in January, 1975, it was reported that shale oil would probably impact more directly than coal liquids on future jet fuel production. Our experimental data now indicates that shale oils are indeed more suitable than coal liquids for the direct production of current specification aviation turbine fuels via catalytic hydroprocessing. Hydroprocessed shale liquids have a paraffin-aromatic-naphthene distribution similar to that of petroleum derived fuels, whereas coal liquid derived products are low in paraffins and the hydroprocessing, in general, simply converts the coal liquid fuel from one rich in aromatics to one rich in naphthenes without substantially increasing the paraffin content.

In the experimental phase, herein described, a processing sequence employing fractional distillation and catalytic hydrogenation was used to produce "synthetic" jet fuels from both shale oil and coal-derived syncrudes. Three shale oils and two coal liquids, obtained from the respective process developers, were investigated. Feed fractions encompassing the jet fuel boiling range were distilled from the starting crude oils and hydrotreated at varying severity over nickel and/or cobalt-molybdenum catalysts. Final narrow-cut (Jet A) and/or wide-cut (JP-4) jet fuels oils were blended from the hydrotreated products.

From the inspections obtained on the final jet fuel blends, including results of the Jet Fuel Thermal Oxidation Tests (JFTOT), it would appear that the production of jet fuels from shale oil-derived crude oils is technically feasible, and should be more straightforward than would be the comparable production from coal-derived oils. Hydroprocessing severity is important to the production of specification fuels. Production of specification jet fuel from shale liquids will require at least a moderate severity operation employing a 1500 psi total pressure. Final fuels prepared from coal-derived fuels, however, did not meet density specifications unless hydrotreated at high severity conditions employing 2200 psi pressure. Moreover, there was indication that catalytic operations with coal-derived oils would be much more troublesome, or expensive, than with shale-derived oils, and might require extensive further catalyst development before becoming practicable. Increased processing severity, in general, improved the thermal stability and decreased the aromatic and nitrogen content of the product fuel. Sulfur levels of the processed fuels were all well below specifications at all processing severity levels.

The experimentally obtained process and analytical information will be used in the third phase of the program to provide a basis for an engineering and economic evaluation of the effect of the use of synthetic crude in a refinery processing both petroleum and synthetic crude to produce a full product slate including aircraft turbine fuels.

SECTION II

INTRODUCTION

Domestic petroleum product production is now, and is forecast to continue to be (National Petroleum Council, 1973), heavily dependent on foreign crude oil feedstocks. Wide recognition of this dependence has led to renewed interest in the production of hydrocarbon liquids from coal and shale deposits to augment the domestic fuel base. The degree to which synthetic fuels developments mitigate foreign dependence is of obvious significance to the logistics support planning of the Armed Forces.

We have previously reported (Shaw, Kalfadelis, Jahnig, 1975) on the first phase of a program sponsored by the U. S. Air Force Systems Command to determine the feasibility of producing aviation turbine fuels, in particular, from other-than-normal petroleum sources. In Phase I, literature data relating to the extent of domestic mineral resources and to the many proposed processes for the extraction or transformation to crude fuel liquids were assessed. An attempt was made to clarify material and energy balances and the investment and cost pictures, and to gauge the environmental impact, of proposed mining and manufacturing operations. Approaches to the production of finished fuels from the crude liquids, based on current petroleum oil technology, were also assessed.

Phase I concluded that shale-derived oils should be preferentially investigated as a source of aviation turbine fuels, both because they more nearly resemble natural petroleum than do other synthetic crudes, and because significant quantities of shale oil are expected to come onto the market before coal-derived materials are available. The properties of coal-derived liquids, on the other hand, make them ideal for the production of other finished products, such as certain motor gasolines, and could add indirectly to aviation turbine fuel availability by permitting back-out of regular petroleum crude from gasoline manufacture. Moreover, specifically-refined coal liquid fractions might be blended into aviation fuels that were otherwise derived from petroleum sources; or coal liquids, which have generally higher density than shale or petroleum oils, might form the basis of a completely new class of jet fuels, assuming a complementary engine development effort were forthcoming. Finally, we concluded that the acquisition of hard data for the processing of synthetic crude oils should be given priority to permit formulation of intelligent policy and projections for the future uses of synthetic fuels.

We were able to begin to follow up on this latter conclusion in Phase II, the experimental segment of the instant program, in which our object was to determine whether specification JP-4 and/or Jet A aviation fuels could be produced from synthetic crude oils. This report discusses the experimental hydrotreatment of selected synthetic crude oil fractions. Subsequent work in Phase III of the program will use the experimentally obtained process and analytical information as a basis for an engineering and economic evaluation of the effect of the use of synthetic crude oil in a combined petroleum and synthetic refinery.

SECTION III

EXPERIMENTAL

An automated catalytic hydrogenation system was employed experimentally to hydrotreat specific synthetic crude oil fractions. The hydrogenation system included facilities for the continuous feeding of oil and hydrogen treat gas, and for the continuous depressurization and collection of hydrotreated oil product. The system was arranged for remote operation. The operating logic that evolved for the system called for semi-attended operation, consistent with maximum operating safety and experimental flexibility.

This section describes the design and operation of the experimental hydrogenation system.

3.1 Design Considerations

3.1.1 Hazards Considerations

The experimental hydrogenation system which became available to this program was located in a laboratory building which had been designed expressly to protect operating personnel from the effects of detonation of contained equipment. The design and construction of the experimental system was predicated on placement of the unit in a reinforced-concrete high-pressure (blast) cell within the building.

The cell employed for placement of the unit has an available floor space of approximately 268 square feet (see Figure 3-1). The ceiling is at about 15 feet. The cubicle is surrounded on all sides except one by reinforced concrete walls, roof, and floor with a minimum thickness of eighteen inches. Vertical walls separating our cell from those adjacent are surrounded additionally by brick walls eight inches thick.

Sliding, laminated boiler-plate doors three-inches thick provide access through opposite side walls. Observation ports on the front, or operating, wall are constructed of three four-inch-thick blocks of optically-clear Plexiglass set into welded steel frames, and separated from each other by two-inch air spaces. A false wall of ½-inch-thick foamed plastic serves as windbreak off the back of the cell, which faces a reinforced earthen bank some thirty-feet thick, raised about five feet higher than the building.

The hydrogenation unit's feed systems for gas and liquids, feed filters, and flow control loops are located at one end of the cell. One-half-inch-thick Plexiglass sheeting arranged with sliding doors is used to protect operators from spray from small leaks which may develop in this area, as from pinholes in pressure gauges or leaks in vent piping downstream of safety valves or rupture discs.

The unit's product recovery, recycle, and sampling systems are located at the opposite end of the cell. The unit's sandbaths, containing the reactors, are located in the central working area (see Figure 3-1).

Hazards design is based on division of the cell's working areas into three classifications:

- Area "A" (filter and sampling areas) to which the operator has access, and in which mechanical repairs are permitted, while the unit is in operation.
- Area "B" (pump and compressor areas) in which pump and compressor servicing and/or repair is permissible on issuance of a bona fide work permit.
- Area "C" (pressurized hydrogen storage and reactor areas) which is "off limits" to all personnel unless the unit is shut-down and in static condition. This area is chained off during unit operation to provide a visual reminder of the "off limits" status.

The blast cell employed was originally designed to contain the detonation of twenty pounds of TNT (equivalent) without affecting adjoining cells, and the embankment system design would so deflect and attenuate the resultant blast pressure wave that windows in the nearest buildings would be subjected in the event to a very small fraction of their ultimate breaking strength.

The front, or operating, wall of the cell is arranged to permit explosion-proof introduction of mechanical, pipe, and electrical linkages to equipment contained in the cell to facilitate remote operation. The cell is internally supplied with utilities, including lighting, water, steam, vacuum, utility air, instrument air, low-and-high-pressure nitrogen, and electricity. High-capacity exhaust blowers mounted on the roof of the building take suction on the cells, maintaining internal pressures always slightly less than pressure in the occupied portion of the building. The cell exhaust system is provided with pressure, flow, and thermal alarms, which sound if malfunction or interruption occurs. Heated air is drawn into the cells through louvres for winter operations. All fixtures and fittings in the cell are explosion- or spark-proof, and mechanical design is consistent with the explosion pressure rating.

A special ultra-high-pressure (6000 psig) nitrogen system servicing the cell was installed to facilitate pressure testing and related high-pressure operations. We also provided a special gas cylinder bank and distribution manifolds for the calibrating gases required for the gas chromatographs.

Hydrogen for the system is taken from a high-pressure truck trailer supply located about 150 feet from the building. Hydrogen is available at the cell (and from the trailer's depressuring station) at about 800 psig. The supply piping is permanent, and the supply system

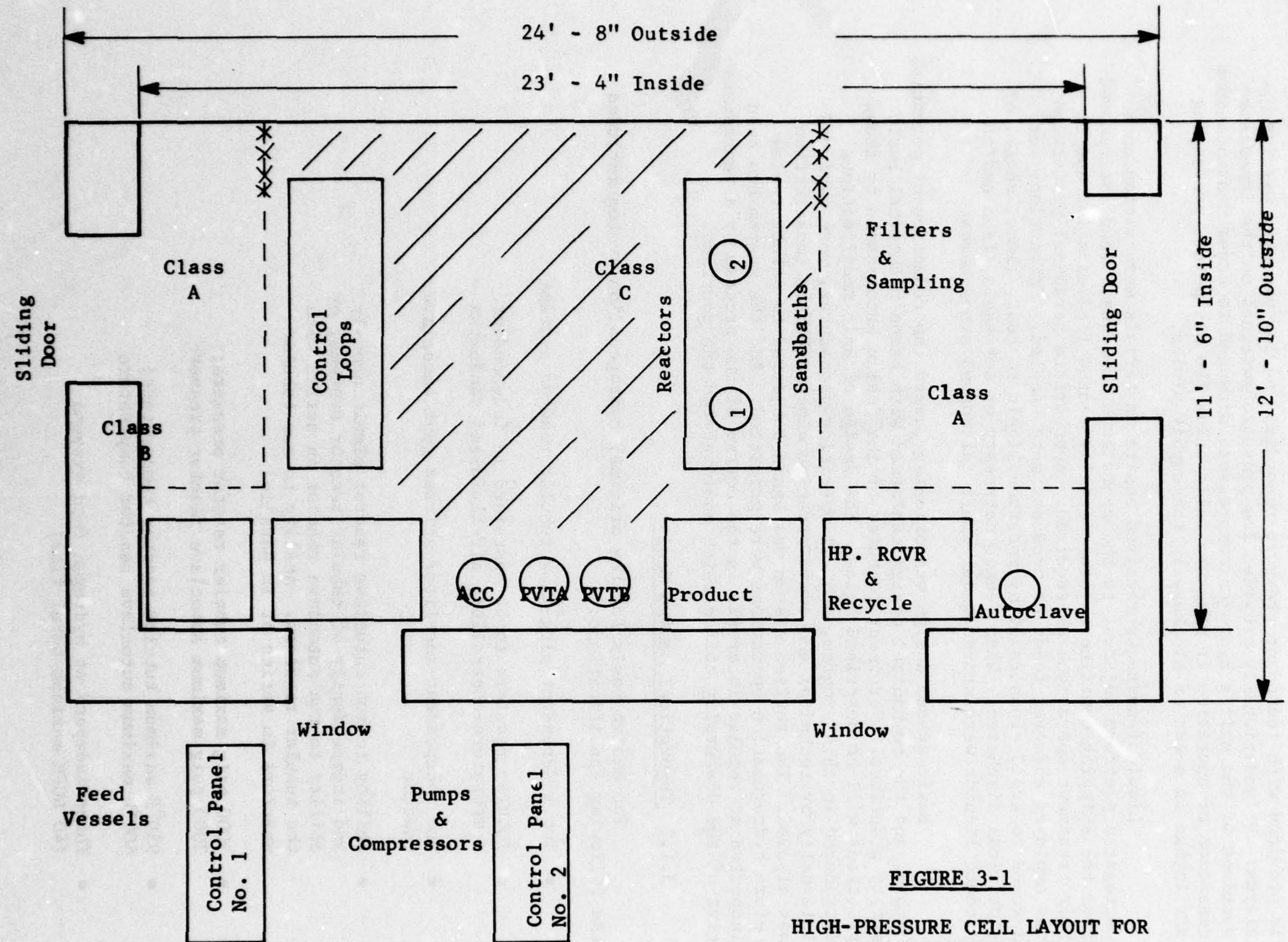


FIGURE 3-1

HIGH-PRESSURE CELL LAYOUT FOR HYDROGENATION SYSTEM

is provided with redundant pressure recording and low-pressure warning alarms. We additionally provided low-pressure switches on the immediate suctions of the unit's hydrogen compressors arranged to cause instantaneous cessation of operation if pressure falls below the set point, preventing air intake in event of blockage in the supply piping.

Liquid feedstocks received onsite in barrels were stored on a segregated platform adjacent to the operations building. Feed was removed from the shipping containers into specially-vented feed cans for use in hydrotreatment operations as required. Appropriate personnel protection was employed whenever feeds or products were handled. Precautions were invoked to avoid exposure of hydrocarbon liquid to heat, flame, shock, or electrical discharge. When deemed necessary or advisable, feed and/or product liquids were stored under inert (nitrogen) atmospheres.

Basic system design was oriented toward the reduction of potential hazard, and the mechanical design conformed with Exxon's internal basic safety practices. Pertinent features of the design encompassed by these practices will be described below. The design of unit modifications introduced in this program, and all operating procedures, were reviewed internally by technical and administrative experts before construction was allowed. The revised system was again subjected to safety review before hydrogenation operations were permitted. And the system has been inspected at regular intervals in the course of the program by a representative of the disbursing office which administered the contract.

3.1.2 Theoretical Design Basis

The design basis for the original hydrogenation system included the following specifications:

- Two independent plug-flow tubular reactor systems
- Tubular reactors to be contained in independent temperature-controlled, air-fluidized sandbaths
- One independent one-liter stirred tank autoclave reactor
- Ability to run autoclave reactor simultaneously and independently of tubular reactor systems; or ability to run autoclave reactor in series with the tubular reactors. Ability to run tubular reactors in series or in parallel
- 5000 psig maximum tubular reactor pressure; 3000 psig maximum autoclave reactor pressure
- 950°F maximum tubular reactor temperature; 600°F maximum autoclave reactor temperature
- Three independent hydrogen feed systems (40 SCFM maximum total flow)

- Two independent liquid feed systems (4000 cc/hr maximum each)

- Two independent additive liquid feed systems (1 cc/hr minimum and 8 cc/hr minimum)

- One liquid recycle system (4000 cc/hr maximum)

It was also decided to fix the tubular reactor systems in an elevated position, permitting a lowerable sandbath configuration (see Figure 3-2) to provide access to an intact (pressurized) system.

The sandbath-contained tubular reactors each consist of a bundle of up to sixteen 5/16-inch I.D. reactor tubes five-feet long. Reactor tubes may be packed with catalyst, and are arranged, normally, for down-flow operation.

The autoclave reactor consists of a one-liter stirred tank, and may be fitted with a stationary wire basket holding about 50 cc of catalyst. ΔP cells are used to control flows and levels.

Effluent from a reactor system may be led to a knock-out tank on which the recycle pump takes suction, and from which it can deliver fluid back to the reactor system inlet. Effluent which is not recycled may be led to a second reactor, or may be cooled, separated, depressured, measured, and collected.

3.2 Hydrogenation System

3.2.1 Hydrogen Feed System (See Figure 3-3)

Hydrogen is supplied to the unit via permanent piping from a truck tube trailer and an associated depressuring/regulation station located approximately 150 feet from the building housing the unit. Hydrogen from the depressuring station is also piped to other buildings/units.

Hydrogen taken from the entering manifold at about 800 psig is compressed by two AMINCO air-operated compressors into a high-pressure accumulator vessel. The accumulator is maintained at pressure through the action of pre-set master control high- and low-pressure pressure switches which start and stop the compressors as the accumulator pressure varies.

Hydrogen from the accumulator goes to one of two PVT tanks (pressure storage vessels) via a downstream preloaded regulator. In effect, the accumulator vessel and the PVT tank not onstream to a reactor are simultaneously tied to the hydrogen compressor discharge through the preloaded regulator; hydrogen flow to the PVT tank from the accumulator ceases when PVT tank pressure reaches the preloaded regulator pressure, causing backup of the accumulator pressure and ultimate shut-down of the hydrogen compressors.

FIGURE 3-2

FLUIDIZED AIR SANDBATH HEATERS FOR HYDROGENATION SYSTEM

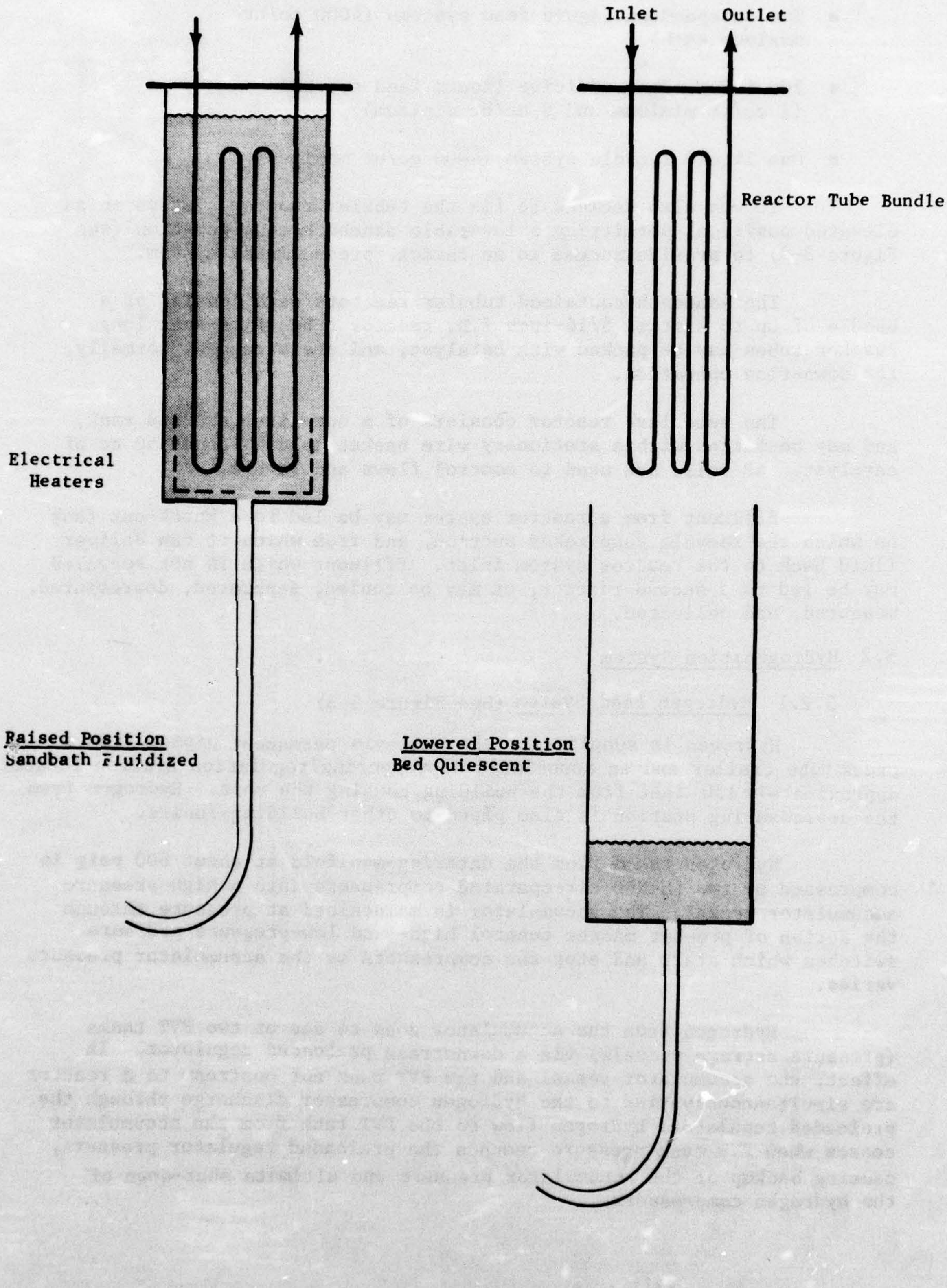
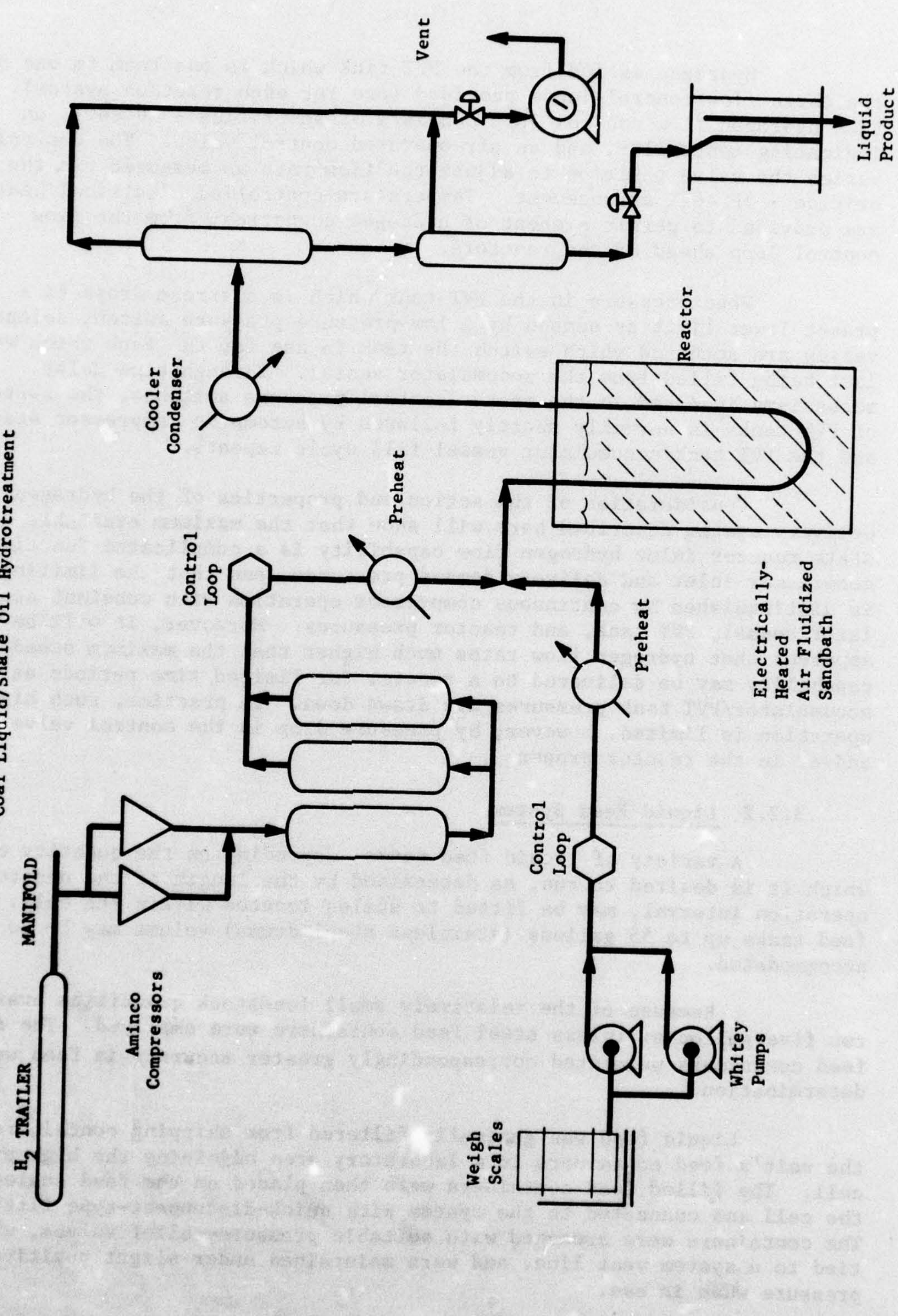


FIGURE 3-3

HYDROGENATION SYSTEM

Coal Liquid/Shale Oil Hydrotreatment



Hydrogen is fed from the PVT tank which is onstream to one of the three flow control loops provided (one for each reaction system). Each hydrogen flow control loop consists of an orifice - ΔP cell, an indicating controller, and an air-operated control valve. The controller varies the valve position to adjust the flow rate as measured via the orifice - ΔP cell arrangement. Temperature-controlled electrical heaters are provided to permit preheat of hydrogen downstream from the flow control loop ahead of the reactors.

When pressure in the PVT tank which is onstream drops to a preset lower limit as sensed by a low-pressure pressure switch, solenoid valves are actuated which switch the tank in use for the tank which was last being filled from the accumulator vessel. Through time-delay mechanisms inserted in the master-control pressure switches, the switching of PVT tanks is normally shortly followed by automatic compressor startup, and the PVT tank/accumulator vessel fill cycle repeats.

Consideration of the action and properties of the hydrogen delivery system described here will show that the maximum available steady-state reactor inlet hydrogen flow capability is a complicated function of compressor inlet and delivery demand pressures, and that the limiting flow is distinguished by continuous compressor operation with constant accumulator vessel, PVT tank, and reactor pressures. Moreover, it will be apparent that hydrogen flow rates much higher than the maximum steady-state capability may be delivered to a reactor for limited time periods as accumulator/PVT tank pressures are drawn down. In practice, such high flow operation is limited, however, by pressure drop in the control valve orifice and/or in the reactor proper.

3.2.2 Liquid Feed System

A variety of liquid feed tanks, depending on the quantity of feed which it is desired to run, as determined by the length of the unattended operation interval, may be fitted to scales located within the cell. Two feed tanks up to 55 gallons (stainless steel drums) volume may be so accommodated.

Because of the relatively small feedstock quantities available, two five-gallon stainless steel feed containers were employed. The smaller feed containers permitted correspondingly greater accuracy in feed weight determination.

Liquid feed was generally filtered from shipping containers into the unit's feed containers in a laboratory area adjoining the high-pressure cell. The filled feed containers were then placed on the feed scales within the cell and connected to the system with quick-disconnect-type fittings. The containers were arranged with suitable pressure-relief valves, which were tied to a system vent line, and were maintained under slight positive nitrogen pressure when in use.

Two duplex Whitey metering pumps with pumping heads 180° out-of-phase take suction on the feed containers and deliver liquid to the appropriate reaction system via a back pressure/flow control loop. A Mity-Mite preloaded back-pressure regulator bypasses the pump discharge to the pump suction, maintaining pump discharge pressure. Flow rates are controlled by indicating controllers utilizing orifice-ΔP cells and appropriate air-operated flow control valves. The flow control loops are identical in their makeup with those used for the hydrogen systems. Liquid feed also may be preheated ahead of the respective reactors.

Special liquid additive delivery systems are provided which may be used to deliver liquids to the reaction systems at very low, controlled rates. A flow control loop identical with those used in the hydrogen and liquid feed systems is provided to control the feeding of liquid additive from a high-pressure blowcase, which is maintained at pressure with hydrogen from the accumulator. This system is usable down to flow rates of about 6-8 cc per hour.

For liquid additive delivery rates below the level of control available from the control loop, a duplex Ruska pump may be fitted which can feed liquids positively and reliably at rates down to less than one cubic centimeter per hour. In this case, the two heads of the Ruska pump are 180° out-of-phase, with one head filling as the other discharges. Ruska pump suction is arranged also from the high-pressure liquid additive blowcase, and discharge is arranged into mixing tees at the reaction system inlets.

3.2.3 Reactor and Recycle Systems

The "sandbath" tubular reactors consist of a total of up to sixteen downflow tubes, which may be packed with catalyst, installed in two constant-temperature, air-fluidized sandbaths. The tubes are normally 9/16-inch O.D. by 5/16-inch I.D. of Type 316 stainless steel, four feet-nine inches long. The tube end connections consist of two couplings welded together and drilled to provide a fluid path from one coupling to the next. Hence each end of a reactor tube terminates in one of these "H"-shaped connectors. The quarter-inch transfer lines which connect one reactor tube to the next similarly attach at the "H" connectors. Thermocouples and/or sampling taps may be inserted at the outboard ends (top and bottom) of each "H", providing extreme flexibility in this regard. Each sampling arrangement consists of double block needle valves and capillary stainless steel tubing, which discharges into a vented and purged glass receiver.

Reactor bundles may be operated either in series or in parallel. Liquid feed and hydrogen (and liquid additive, if employed) are premixed in a mixing tee at the reaction system(s) inlet. Both the liquid feed and entering hydrogen may be preheated if desired.

The heat capacity of the fluidized sandbath is sufficiently large to swamp reaction heat effects in all instances involving hydrogenation so far investigated. A total of twelve reactor thermocouple readings may be recorded. In normal steady-state operations, reactor temperature readings are virtually identical, within a range of less than 20 Fahrenheit degrees at a temperature level of 700 degrees Fahrenheit.

Effluent from the last reactor tube is led to a knockout tank. A Zenith gear pump is arranged to take suction on the knockout tank and deliver liquid effluent back to the reactor inlet if such recycle is desired. Recycle flowrate is regulated by an orifice/ΔP-cell sensor which regulates the Zenith pump output.

Effluent which is not recycled is cooled and separated, the gas phase being released under pressure control, and the liquid phase under level control. Effluent gas is metered and sampled before being vented above the building from safety stacks. Several arrangements are available to collect liquid product, depending on the length of the unattended operation interval, and on the liquid flow rate in use. In general, liquid product is collected in a glass-pipe receiver which may be sponged with dry nitrogen to strip dissolved H_2S, NH_3, and/or H_2O from freshly discharged material. Liquid product is permitted to overflow the sponger vessel into larger, vented containers as required by the collection rate and the length of the unattended operation interval.

3.2.4 Start Up, Operation, Shut-Down Procedures

Procedures for start up, operation, and shut down for the hydrogenation system are appended to this report (See Appendices I-III).

3.3 Feedstock Preparation

In this section are described the procedures used to characterize the synthetic crude samples obtained from the various process developers, and to separate the feedstocks for the hydrogenation experiments performed in the program.

We were committed to investigate three shale-derived crude oils and two coal-derived crudes. The particular crude oils employed were chosen from a schedule of available oils in joint conference with the government Project Engineers. The criteria employed were many, but included the proviso that all crude processing, and the corresponding starting minerals and mining operations, be wholly domestically sited. Certain crude oils derived from well-known processes, such as the FMC COED system, were excluded because other organizations had investigated, or were committed to investigate, them in similar contexts.

We acknowledge the cooperation of the respective process developers in the furnishing of samples. Only one sample of each developer's output was investigated in this program.

3.3.1 Crude Assay Procedure

Each synthetic crude sample (generally one 42-gallon barrel sample was involved) was shipped to our Crude Assay Laboratory at Baytown, Texas for assay. The crude assay involved a two-stage, atmospheric/vacuum distillation in a metallic still with charge capacity of about 30 gallons, and

with fractionation capability equivalent to about fifteen theoretical plates (atmospheric).

Each crude liquid was separated into multiple cuts, or fractions, by the distillation procedure. Typically, some twenty-five to forty distillate fractions were collected, encompassing all of the material in the charge crude boiling up to about 1050°F. Each distillate fraction, and the residue bottoms, from each distillation was then characterized through multiple analyses. The resulting analytical information was collated into an assay report.

Crude assay information for normal petroleum crude oils obtained in the manner described is typically used to estimate or extrapolate processing yields in refinery operations. Depending on the extent of a particular operator's data base for similar crude oils, the performance of new crude oils may frequently be very closely estimated. However, in the case of any new crude oil, as in the cases of the materials treated in this study, anomalies may be encountered. Risks involved in the employment of numerical extrapolations based on crude assay information may be rendered vanishingly small only by widening the data base sufficiently to include all crude liquids and crude liquid permutations, however.

3.3.2 Paraho Shale Oil Assay

The crude assay for the Paraho shale oil sample is attached as Appendix V to this report. Our sample of Paraho shale oil was obtained from the Paraho Development Corporation, Rifle, Colorado. Standard Oil Company of Ohio organized a 17-member development organization to investigate the Paraho retorting process in depth, beginning about 1970. The Phase 1 Final Report, AFAPL-TR-75-10, includes detailed descriptions of all of the syncrude processes referred to in this report.

3.3.3 TOSCO II Shale Oil Assay

Our TOSCO II shale oil sample was obtained from The Oil Shale Corporation, Golden, Colorado. The TOSCO II retorting process is distinguished by the circulation, through the pyrolysis system, of ceramic pellets or balls, a concept which was investigated at the Denver Research Institute beginning about 1956.

The crude assay for the TOSCO II shale oil is attached as Appendix VI to this report.

3.3.4 Garrett (Occidental) Shale Oil Assay

The Garrett (or Occidental) Research Corporation shale oil sample is distinguished by having been produced in-situ. The crude assay for the Garrett shale oil is attached as Appendix VII to this report.

3.3.5 Synthoil Coal Liquid Assay

Synthoil is another Bureau of Mines (now ERDA) development, utilizing a unique coal slurry catalytic hydrogenation reaction system to produce synthetic crude oil. A five- to ten-barrel-per-day pilot plant, which represents a significant scale-up of the facility in which our sample was produced, is now being constructed at the Pittsburgh Energy Research Center.

The crude assay for the Synthoil coal liquid, along with a letter describing the sample preparation, is attached as Appendix VIII to this report. Note that, due to operating difficulty with the assay system, the Synthoil assay extends only to 700°F.

3.3.6 H-Coal Liquid (Assay)

The H-Coal process has been under development by Hydrocarbon Research, Inc., Trenton, New Jersey for over ten years, representing an extension of the ebullated bed hydrogenation technology originally employed to convert heavy petroleum fractions to lighter oils.

Our sample of H-Coal liquid (fifteen gallons), purchased from Hydrocarbon Research, was labeled "Atmospheric Overhead, Sample No. LO-73", obtained in H-Coal's PDU Run No. 130-63-13B. HRI provided inspections of the coal feed used in Run 130-63, which are attached as Appendix IX to this report. HRI has otherwise declined to provide any additional information regarding the preparation of this material, or relating to the yield of this particular fraction from the H-Coal liquefaction system.

There was insufficient material purchased to permit a crude assay to be obtained for the H-Coal sample. The sample was already a distillate, however, whose boiling range encompassed the desired jet fuel boiling range. Our ASTM D-86 distillation analysis for this sample is attached in Appendix IX. Other inspections for this feed sample are shown in Tables 4- 39, 40, and 41.

3.3.7 Feedstock Distillation Procedure

We had decided in the first phase of this program to employ distillate fractions, encompassing the jet fuel boiling range, separated from each whole crude, as feeds to the hydrogenation experiments. Because the crude assay procedure consumed, in general, about twenty-five gallons, or one-half barrel, of sample, the quantity of feed available to the program, in each case, amounted to that quantity which could be derived from the half-barrel remaining.

In general, a distillate fraction containing all material in the original whole crude which boiled up to about 563°F was employed in the hydrogenation experiments performed at our normal- and low-severity conditions. In selected cases (see Section 4.1.9), distillate fractions which included all material boiling up to 650°F and/or 700°F were fed to high-severity experiments.

The IBP-(Initial Boiling Point)-to-563°F fractions were distilled from the whole crudes at Baytown in the same equipment used for the crude assays. These fractions were shipped to Linden for hydrotreatment, along with small amounts of the original whole crudes which had not been charged either to crude assay distillation or to feedstock distillation. From these small quantities of remaining whole crude, the IBP-to-650°F and/or IBP-to-700°F distillate fractions, which were fed to some high-severity operations, were separated in glass equipment having about the same fractionation capability as the Baytown equipment.

In Table 3-1 are summarized the crude assay still data through the IBP-to-650°F feedstock distillation range for the Paraho shale oil. Reference to Table 3-I will show that no more than about 11.7 weight per cent of the sample boiled below 563°F, or was within the jet fuel range. Some 23.4 weight per cent of the total sample boiled below 650°F.

In Table 3-2 are summarized the curde assay still data through the IBP-to-650°F feedstock distillation range for the TOSCO II shale oil. Note that about 23.0 weight per cent of the sample boiled below 563°F, or about double that for the Paraho case. Moreover, the initial boiling point of this material was lower than for Paraho, so that considerably more light ends were present in the separated feedstock, permitting the preparation of both wide- and narrow-cut jet fuels from our downstream processing (see Section 4.3.3).

Table 3-3 summarizes the crude assay still data for the Garrett shale oil. About 25.5 weight per cent of the Garrett sample boiled below 563°F, about the same as for the TOSCO II sample. However, the Garrett "kerosene fraction" was considerably heavier than was the TOSCO II fraction, and only narrow-cut fuels were derived from the low- and normal-severity Garrett experiments (see Section 4.4.4). Note, however, that some 43.5 weight per cent of the Garrett sample boiled below 650°F, compared with only 31.2 weight per cent of the TOSCO II sample.

TABLE 3-1

FEED DISTILLATION SUMMARY

PARAHO WHOLE SHALE OIL

	WEIGHT (GMS)	WT. PERCENT (ON HC CHARGE)	VOLUME (CC)	VOL. PERCENT (ON HC CHARGE)	DENSITY (GMS/CC)
GROSS CHARGE	70,261		74,979		
H_2O IN CHARGE	- 355	0.51	- 379	0.51	
NET HC CHARGE	69,906	100.00	74,600	100.00	0.9371
IBP TO 563°F					
OVERHEAD	8,208	11.74	9,528	12.77	0.8615
IBP TO 650°F					
OVERHEAD	16,378	23.43	18,672	25.03	0.8771
HOLDUP	221	0.32	230	0.31	
BOTTOMS	53,530	76.57	55,801	74.80	0.9593
TOTAL ACCOUNTED	70,129	100.32	74,703	100.14	

TABLE 3-2

FEED DISTILLATION SUMMARY

TOSCO WHOLE SHALE OIL

	WEIGHT (GMS)	WT. PERCENT (ON HC CHARGE)	VOLUME (CC)	VOL. PERCENT (ON HC CHARGE)	DENSITY (GMS/CC)
GROSS CHARGE	72,348		78,071		0.9267
VOLATILES IN CHARGE	- 76	0.11	- 126	0.16	
NET HC CHARGE	72,272	100.00	77,945	100.00	
IBP TO 563°F					
OVERHEAD	16,637	23.02	20,337	26.09	0.8181
IBP TO 650°F					
OVERHEAD	22,571	31.23	26,949	34.57	0.8375
HOLDUP	224	0.31	230	0.30	
BOTTOMS	49,245	68.14	50,461	64.74	0.9759
TOTAL ACCOUNTED	72,040	99.68	77,640	99.61	

TABLE 3-3

FEED DISTILLATION SUMMARY

GARRETT (OCCIDENTAL) WHOLE SHALE OIL

	WEIGHT (GMS)	VOL. PERCENT (ON HC CHARGE)	VOLUME (CC)	WT. PERCENT (ON HC CHARGE)	DENSITY (GMS/CC)
GROSS CHARGE	76,430		83,989		
H_2O IN CHARGE	- 4,751	6.63	- 5,221	6.63	
NET HC CHARGE	71,679	100.00	78,768	100.00	0.9100
IBP TO 563°F					
OVERHEAD	18,248	27.15	21,388	25.46	0.8532
IBP TO 650°F					
OVERHEAD	31.188	45.77	36,052	43.51	0.8651
HOLDUP	215	0.29	230	0.30	
BOTTOMS	39,910	54.14	42,648	55.68	0.9358
TOTAL ACCOUNTED	71,313	100.20	78,930	99.49	

TABLE 3-4

FEED DISTILLATION SUMMARY

SYNTHOIL WHOLE COAL OIL

	WEIGHT (GMS)	WT. PERCENT (ON HC CHARGE)	VOLUME (CC)	VOL. PERCENT (ON HC CHARGE)	DENSITY (GMS/CC)
GROSS CHARGE	85,956		82,011		1.0481
VOLATILES IN CHARGE	- 100	0.12	- 166	0.20	
NET HC CHARGE	85,856	100.00	81,845	100.00	
IBP TO 563°F					
OVERHEAD	20,050	23.35	21,654	26.46	0.9259
IBP TO 650°F					
OVERHEAD	32,683	38.07	34,735	42.44	0.9409
HOLDUP	256	0.30	230	0.28	
BOTTOMS	52,705	61.39	47,304	57.80	1.1142
TOTAL ACCOUNTED	85,644	99.76	82,269	100.52	

Table 3-4 summarizes the crude assay still data for the Synthoil coal liquid sample. Interestingly, some 23.4 weight per cent of the Synthoil sample boiled below 563°F, very nearly the identical fraction for the TOSCO II sample. However, the Synthoil "kerosene fraction" was considerably more dense than were any of the corresponding shale oil fractions, and only narrow-cut fuels could be prepared from our low- and normal-severity hydrotreatment experiments (see Section 4.5.3). The quantity of the Synthoil sample which boiled below 650°F, at 38.1 weight per cent, was between the corresponding quantities for the TOSCO II and Garrett shale oil samples.

There was no crude assay performed on the H-Coal sample (see Section 3.3.6 above). However, all of the sample boiled below 563°F, and its density was very near to those of the Garrett or Paraho "kerosene fractions". Moreover, the H-Coal sample contained sufficient lighter-boiling components to permit preparation of both narrow- and wide-cut jet fuels from the low- and normal-severity hydrotreatment experiments (see Section 4.6.3).

Feedstocks are discussed additionally in Section V of this report.

3.4 Catalysts

Only two catalysts were employed in the program. HDS-3A, a nickel-molybdenum-on-alumina hydrotreating catalyst supplied by American Cyanamid Company, Bound Brook, New Jersey was our "standard" working catalyst. Our sample, in the form of 1/16-inch pellets, was designated "MTG-S-0658, BB-75-336". When loaded into our reactor system, the catalyst sample had an apparent bulk density of 0.727 grams per cubic centimeter. This catalyst was indicated to contain 3.0 to 4.0 weight per cent NiO and 14.5 to 16.0 weight per cent MoO_3 by the vendor.

The second catalyst we employed was a cobalt-molybdenum-on-alumina, Nalcomo 477, supplied by Nalco Chemical Company, Chicago, Illinois. Our sample, also in the form of 1/16-inch pellets, was designated "75-5419 A, February 6, 1975". This catalyst exhibited an apparent bulk density of 0.648 grams per cubic centimeter in our reaction system. This catalyst was indicated to contain 3.5 weight per cent CoO and 12.5 weight per cent MoO_3 by the vendor.

All new catalyst charges were dried and calcined in dry air at 900°F, and presulfided using an H_2S/hydrogen gas mixture <u>in-situ</u> before use in hydrotreatment. The gas flow/temperature program used for presulfiding was identical for all catalyst charges, and corresponded to the schedule recommended by American Cyanamid for pretreatment of HDS-3A.

3.5 Experimental Procedure

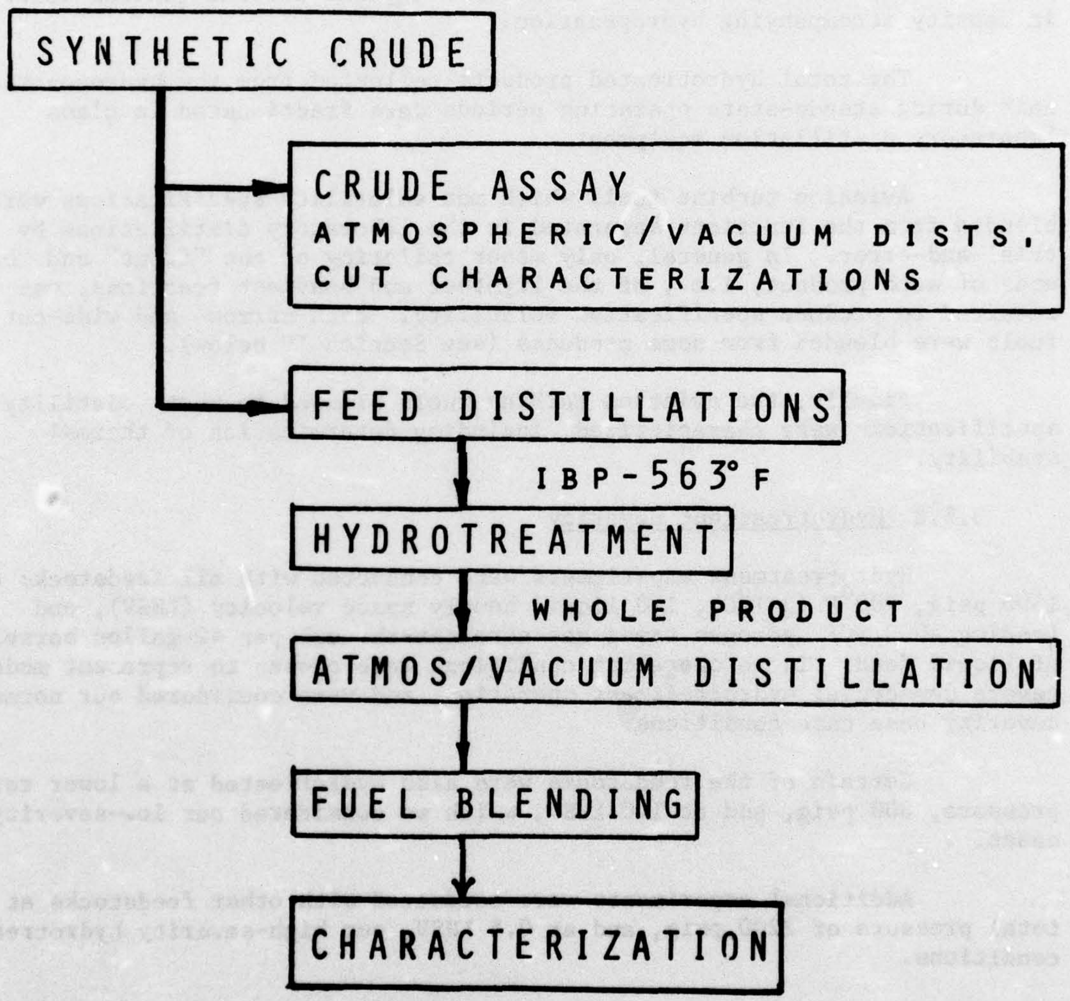
The experimental procedure employed in our program is summarized in this section.

3.5.1 Overall Procedure

The overall experimental sequence is shown schematically in Figure 3-4. As has been indicated, each synthetic crude oil sample was firstly assayed or analyzed (H-Coal coal liquid was not assayed because of insufficient sample).

FIGURE 3-4

EXPERIMENTAL PROCEDURE



From each synthetic crude oil sample, a "kerosene fraction", including all material boiling up to about 563°F, was distilled (H-Coal coal liquid was a distillate as received, with a final boiling point below 563°F and was not redistilled).

The "kerosene fractions" derived from the various crude oil samples were hydrotreated at varying severity in the experimental hydrogenation system described above. The kerosene fraction was purposely taken to include some material heavier than that found in the desired finished fuels to compensate for any cracking tendency, and for the general decrease in density accompanying hydrogenation.

The total hydrotreated products collected from the hydrogenation unit during steady-state operating periods were fractionated in glass laboratory distillation equipment.

Aviation turbine fuels which met volatility specifications were blended from the fractions separated in the laboratory distillations by trial-and-error. In general, only minor tailoring of the "front" and "back" ends of each product, i.e., of the lightest and heaviest fractions, was required to produce specification volatility. Both narrow- and wide-cut fuels were blended from some products (see Section IV below).

Finally, the aviation turbine fuels blended to meet volatility specifications were characterized, including determination of thermal stability.

3.5.2 Hydrotreatment Severity

Hydrotreatment experiments were conducted with all feedstocks at 1500 psig, 700°F (371°C), 1.0 liquid hourly space velocity (LHSV), and feeding 4000 SCF hydrogen treat gas straight-through per 42-gallon barrel of liquid feed. These operating conditions were chosen to represent moderately severe commercial hydrotreatment operation, and were considered our normal-severity base case conditions.

Certain of the feedstocks were also hydrotreated at a lower total pressure, 800 psig, and at 1.0 LHSV, which we considered our low-severity cases.

Additional experiments were conducted with other feedstocks at a total pressure of 2200 psig, and at 0.5 LHSV, our high-severity hydrotreatment conditions.

In general, shale liquids were processed over nickel-molybdenum catalyst, and coal liquids over cobalt-molybdenum, although some "cross-over" runs were also made.

At least one final finished fuel blend was prepared from feedstocks derived from each of the five "synthetic crude oils" in the program at each of the three severity levels. There was, however, insufficient feedstock available to permit once-through operation for all feeds at all severities,

so that some high-severity runs represent doubly-hydrotreated products. On the other hand, there was sufficient feedstock available in two cases (TOSCO II and Garrett) to permit feed fractions with endpoints of 650°F and/or 700°F to be additionally separated from the whole crudes and fed to high-severity experiments (see Sections 4.3.1 and 4.4.1 below).

SECTION IV

RESULTS

The experimental hydrogenation system was first operated feeding commercial jet fuels to demonstrate system operation and to test the system's capability, in particular, to operate automatically for long time periods without attention. The system was then operated to hydroprocess the synthetic feedstocks, as these became available from the Crude Assay Laboratory at Baytown, Texas.

In the initial operations, the hydrogenation run length was gradually extended until we were satisfied that there was no particular problem associated with continuous indefinite operation. The primary concerns in this connection were the integrity of the high-pressure reaction system, including the pressurized hydrogen storage and feed systems, the reliability of the hydrogen compressors and liquid feed pumps, and the ability of the provided automation to sense a potentially hazardous condition and to bring the system into a safe standby or shutdown condition.

In retrospect, we found little cause for real concern in those respects. At total reaction pressures up to 4000 psig, there was never any evidence that any part of the system was being unduly stressed. Although the design of the reactor, involving multiple components and closures, led to prolonged searches for leaking fittings on several occasions, the reaction system gave faultless service over hundreds of hours of operation, once integrity had been established. The hydrogen compressors, too, operated for hundreds of hours with only normal maintenance. One machine required major overhaul as a consequence of the failure of a component in its lubrication system. The liquid feed pumps were involved in most of the inadvertent unit shutdowns, although flow stoppage was usually found to be due to particulate matter in feeds, plugged feed filters, or to the development of high pressure drop across the reactor. In all cases of difficulty, system operation was terminated instantaneously automatically, such that there was never occurrence of fire or explosion or evidence of other thermal or pneumatic stress.

Hence hydrogenation operations, which were initially based on fully attended, generally one-shift operation, were ultimately geared to continuous, round-the-clock, seven-day operations with attention provided on a one-shift, five-days-per-week basis. The attention required by the unit included normal maintenance and lubrication of the rotating machinery, the changeout of strategic filter elements, the filling of feed reservoirs and the draining of product receivers, and the maintenance and calibration of the unit's instrumentation. Reaction temperature and total pressure were fixed and constant in most operations. Manipulation of liquid feed and hydrogen flow rates were the principal varied parameters in the course of an operation. Collection of data and preparation of analytical samples were the normal primary operator concerns.

4.1 Chronological System Operations

This section first describes the operations and data gathering in chronological order. References are made to run data sets which are included as Table 4-1.

4.1.1 Initial System Hydrogenation Operations

The initial unit safety inspection (internal Exxon) was held March 3, 1975 by the affected facilities' supervisors, safety supervisor, and pilot plant engineers, following unit modifications incorporated as a consequence of recommendations agreed to in a work status meeting held February 7, 1975.

The initial trial catalyst, a cobalt-molybdenum-on-alumina, was charged to the reactor on March 25, 1975, and presulfided in place using a 10% H_2S/90% H_2 sulfiding gas mixture. The catalyst, designated COMO-0601T, and in the form of 1/8-inch pellets, had been acquired from Harshaw Chemical Company several years previously. A total of 324 cc was charged, distributed among six reactor tubes. These six catalyst-filled tubes, along with two empty preceding tubes which were utilized as a preheater, comprised the total reactor bundle.

In the course of adjusting the temperature control system, fluidization air rates and fluidizing sand levels were varied, involving repetitive lowering and raising of the sandbath vessels. In our system, the reactors are fixed in an elevated position, and the sandbaths which enclose them are raised into position from ground level by pneumatic pistons. The sandbath vessel head seal and a portion of the reactor bundle was damaged as the sandbath vessel was being elevated into position following an adjustment in sand level. Subsequently, it was found that a pipe wrench had fallen into the bath, and had been wedged across the vessel, impeding the upper movement of the bath. The offending wrench predated our operations. It is noted that the system was successfully operated for a large number of cycles before damage was sustained.

Following repair of the reactor sandbath damage, the reactor catalyst charge was resulfided prior to operations because the reactor had been opened briefly in the course of the mechanical repairs.

Liquid feed was started into the unit for the first time on April 11, 1975. The initial liquid feed was Jet A aircraft turbine fuel, which analyzed 765 ppm total sulfur. Initial hydrogenation conditions were 690°F. temperature, 1500 psig total pressure, 10 SCFH hydrogen flow and 500 cc/hr. liquid flow. The reactor system, including the two empty preheater tubes, was indicated to be isothermal throughout.

In the initial week of operations, liquid feed was maintained only during the day shift. The unit's temperature was dropped to 200-300°F overnight, with a small sustaining hydrogen flow, and was increased again daily to the operating region.

TABLE 4-1

HYDROGENATION UNIT RUN SUMMARY

RUN	1A		2A	--	--	3A	
START	1000 5/13/75		1430 5/14/75	1400-5/15	1730-5/15	0900 5/16/75	
END	1430 5/14/75		1400 5/15/75	1730-5/15	0900-5/16	1530 5/16/75	
RUN, HRS.	28.5		23.5	(3.5)	(15.5)	6.5	
CUM. RUN HRS.	28.5		52.0	--	--	58.5	
CUM. ELAPSED HRS.	28.5		52.0	55.5	71.0	77.5	
FEED	JET A		DOCTORED JET A	--	--	DOCTORED JET A	
START WT., LBS.	31.65		18.78	--	--	12.27	
END WT., LBS.	24.38		13.21	--	--	9.17	
TOTAL FEED, LBS.	7.27		5.27	--	--	3.10	
TOTAL PROD. RECOVERED, LBS.	--		--	--	--	--	
RATE, LBS/HR.	0.255		0.237	--	--	0.477	
RATE, GMS/HR.	115.7		107.5	--	--	216.3	
DENSITY, GMS/CC @ 60°F	0.8122		0.8122	--	--	0.8122	
DENSITY, GMS/CC @ 75°F	0.8065		0.8065	--	--	0.8065	
LIQ. RATE, CC/HR.	143.5		133.3	--	--	268.2	
LHSV	0.36		0.34	--	--	0.67	
TOTAL PRESS., PSIG	3000		3000	3000	3000	3000	
TEMP., °F	650		650	650	650	650	
H_2 RATE, SCFH	10.14		9.39	--	12.4	9.68	
H_2 RATE, SCF/BBL	11,240		11,200	--	--	5,740	
FEED							
PARAFFINS	17.8		19.7	FAILURE	LIQUID	19.7	
MONOCYCLOPARAFFINS	--		2.6	OF	FEED	2.6	
DICYCLOPARAFFINS	82.2		77.7	REACTOR	PUMP	77.7	
TRICYCLOPARAFFINS				OUTLET	FAILURE		
ALKYLBENZENES	777.		871.	HEISE		871.	
INDANES+TETRALINS	39.		340.	GAGE			
INDENES							
NAPHTHALENES							
PPM S							
PPM N							
PRODUCT	6 hr.	25 hr.	21.5 hr.			5 hr.	6.5 hr.
PARAFFINS							
MONOCYCLOPARAFFINS							
DICYCLOPARAFFINS	94.4	96.0	96.4			97.3	100.
TRICYCLOPARAFFINS							
ALKYLBENZENES							
INDANES+TETRALINS	4.0	2.6	2.1			2.0	—
INDENES							
NAPHTHALENES							
PPM S	61.	2.	1.			2.	2.
PPM N	< 30.	< 30.	< 30.				

TABLE 4-1 (Cont'd)

RUN	--	4A		--	--	1B
START	1530-5/16	0830 5/19/75		1530-5/19	1600-5/20	1130 5/21/75
END	0830-5/19	1530 5/19/75		1600-5/20	1130-5/21	1630 5/21/75
RUN, HRS.	(65.0)	7.0		(24.5)	(19.5)	5.0
CUM. RUN HRS.	--	65.5		--	--	70.5
CUM. ELAPSED HRS.	142.5	149.5		174.0	193.5	198.5
FEED	--	JP-5		--	--	JP-5
START WT., LBS.	--	25.15		--	--	30.20
END WT., LBS.	--	21.73		--	--	27.80
TOTAL FEED, LBS.	--	3.42		--	--	2.40
TOTAL PROD. RECOVERED, LBS.	--	--		--	--	--
RATE, LBS/HR.	--	0.489		--	--	0.480
RATE, GMS/HR.	--	221.6		--	--	217.7
DENSITY, GMS/CC @ 60°F	--	0.8095		--	--	0.8095
DENSITY, GMS/CC @ 75°F	--	0.8038		--	--	0.8038
LIQ. RATE, CC/HR.	--	275.7		--	--	270.9
LHSV		0.70		--	--	0.68
TOTAL PRESS., PSIG	3000	3000		0	3000	3000
TEMP., °F	670	670		700	650	650
H_2 RATE, SCFH	9.77	9.33		--	6.56	10.36
H_2 RATE, SCF/BBL	--	5,380		--	--	6,080
FEED						
PARAFFINS		81.4				81.4
MONOCYCLOPARAFFINS	PUMP				PUMP	
DICYCLOPARAFFINS	FAILURE				FAILURE	
TRICYCLOPARAFFINS				CATALYST		
ALKYLBENZENES				RESULFIDED		
INDANES+TETRALINS		18.1				18.1
INDENES	LIQUID				LIQUID	
NAPHTHALENES	FEED				FEED	
PPM S		264.				264.
PPM N		34.				34.
PRODUCT		4.5 hr.	7.0 hr.			4 hr.
PARAFFINS						
MONOCYCLOPARAFFINS		100	97.7			95.9
DICYCLOPARAFFINS						
TRICYCLOPARAFFINS						
ALKYLBENZENES						
INDANES+TETRALINS						
INDENES			1.1			4.1
NAPHTHALENES						
PPM S		1.	2.			2.
PPM N		<30.	-			<30.

TABLE 4-1 (Cont'd)

RUN	--	2B	3B	--	4B	
START	1630-5/21	0830 5/27/75	1500 5/28/75	2230-5/28	1100 5/29/75	
END	0830-5/27	1500 5/28/75	2230 5/28/75	1100-5/29	0845 5/30/75	
RUN, HRS.	(136.0)	30.5	7.5	(12.5)	21.75	
CUM. RUN HRS.	--	101.0	108.5	--	130.25	
CUM. ELAPSED HRS.	334.5	365.0	372.5	385.0	406.75	
FEED	--	JP-5	DOCTORED JP-5	--	DOCTORED JP-5	
START WT., LBS.	--	26.51	17.30	--	14.97	
END WT., LBS.	--	19.67	14.97	--	9.70	
TOTAL FEED, LBS.		6.84	2.33		5.27	
TOTAL PROD. RECOVERED, LBS.	--	--	--	--	--	
RATE, LBS/HR.	--	0.244	0.310	--	0.242	
RATE, GMS/HR.	--	101.7	140.9	--	109.9	
DENSITY, GMS/CC @ 60°F		0.8128	0.8110	--	0.8110	
DENSITY, GMS/CC @ 75°F		0.8070	0.8051	--	0.8051	
LIQ. RATE, CC/HR.	--	126.1	175.0	--	136.5	
LHSV	--	0.32	0.44	--	0.35	
TOTAL PRESS., PSIG	200	3000	3000	150	3000	
TEMP., °F	AMB.	650	650	200	650	
H_2 RATE, SCFH	--	9.46	10.77	--	9.66	
H_2 RATE, SCF/BBL	--	11,930	9,790	--	11,250	
FEED						
PARAFFINS	LIQUID					
MONOCYCLOPARAFFINS	FEED			LOW		
DICYCLOPARAFFINS	PUMP	77.2	82.9	LIQUID	82.9	
TRICYCLOPARAFFINS	REPAIR			FLOW		
ALKYLBENZENES	--			ALARM/		
INDANES+TETRALINS	MEMORIAL			SHUTDOWN		
INDENES	DAY	22.5	16.0		16.0	
NAPHTHALENES	HOLIDAY					
PPM S			407.		407.	
PPM N						
PRODUCT		25 hr.	7.5 hr.		5.5 hr.	21.5 hr.
PARAFFINS						
MONOCYCLOPARAFFINS						
DICYCLOPARAFFINS		92.2	89.0		96.9	96.5
TRICYCLOPARAFFINS						
ALKYLBENZENES						
INDANES+TETRALINS						
INDENES						
NAPHTHALENES		5.0	0.0		3.1	3.5
PPM S						
PPM N		1.	<1.		1.	1.

TABLE 4-1 (Cont'd)

RUN	5B		6B	7B	8B	9B
START	0845 - 5/30/75		1630-5/30/75	0845 6/2/75	1615 6/2/75	0900 6/3/75
END	1630 - 5/30/75		0845-6/2/75	1615 6/2/75	0900 6/3/75	1630 6/3/75
RUN, HRS.	7.75		64.25	7.5	16.75	7.5
CUM. RUN HRS.	138.0		202.25	209.75	226.50	234.00
CUM. ELAPSED HRS.	414.5		478.75	486.25	503.00	510.50
FEED	JP-5		DOCTORED PRODUCT	RERUN DOCTORED PROD.	JP-5	JP-5
START WT., LBS.	34.18		30.75	13.85	31.92	21.90
END WT., LBS.	32.04		13.85	11.97	21.90	17.25
TOTAL FEED, LBS.	2.14		16.90	1.88 (1.60)	10.02 (9.54)	4.65 (4.41)
TOTAL PROD. RECOVERED, LBS.	--		--	--	--	
RATE, LBS/HR.	0.276		0.263	0.2507	0.598	0.62
RATE, GMS/HR.	125.3		119.3	113.7	271.3	281.2
DENSITY, GMS/CC @ 60°F	0.8128		0.7977	0.7977	0.8128	0.8128
DENSITY, GMS/CC @ 75°F	0.8070		0.7917	0.7917	0.8070	0.8070
LIQ. RATE, CC/HR.	155.2		149.6	143.6	336.2	348.5
LHSV	0.39		0.38	0.36	0.85	0.88
TOTAL PRESS., PSIG	3000		3000	3000	3000	3000
TEMP., °F	650		650.	700.	700.	700.
H_2 RATE, SCFH	9.55		9.17	9.43	8.67	11.17
H_2 RATE, SCF/BBL	9,780		9,740	10,440	4100	5100.
FEED						
PARAFFINS	77.2				77.2	77.2
MONOCYCLOPARAFFINS						
DICYCLOPARAFFINS						
TRICYCLOPARAFFINS						
ALKYLBENZENES						
INDANES+TETRALINS						
INDENES	22.5				22.5	22.5
NAPHTHALENES						
PPM S	286.		1.	1.	286.	286.
PPM N	30.				<30.	<30.
PRODUCT	3.8 hr.	7.8 hr.	64 hr.	7.5 hr.	16.25 hr.	6.0 hr.
PARAFFINS						
MONOCYCLOPARAFFINS	98.4	96.5	96.5	97.2	96.0	95.6
DICYCLOPARAFFINS						
TRICYCLOPARAFFINS						
ALKYLBENZENES						
INDANES+TETRALINS						
INDENES	1.6	3.5	3.5	2.8	4.0	2.2
NAPHTHALENES						
PPM S	1.	2.	1.	<1.	1.	1.
PPM N	-	-	52.	64.	<30.	59.

TABLE 4-1 (Cont'd)

RUN	10B	--	11B				12B	--
START	1630 6/3/75	1130-6/4	1245 6/4/75				1045 6/6/75	1330-6/6
END	1130 6/4/75	1245-6/4	1045 6/6/75				1330 6/6/75	1400-6/6
RUN, HRS.	19.0	(1.25)	46.0				2.75	(0.5)
CUM. RUN HRS.	253.00	253.00	299.0				301.75	301.75
CUM. ELAPSED HRS.	529.50	530.75	576.75				579.50	580.00
FEED	DOCTORED JP-5	--	PARAHO SHALE				JP-5	--
START WT., LBS.	21.10	--	68.86				25.20	--
END WT., LBS.	9.35	--	36.85				22.80	--
TOTAL FEED, LBS.	11.75 (11.56)		32.01 (29.50)				2.40 (2.75)	
TOTAL PROD. RECOVERED, LBS.								
RATE, LBS/HR.	0.62	--	0.696				0.873	--
RATE, GMS/HR.	280.5	--	315.6				395.9	--
DENSITY, GMS/CC @ 60°F	0.8123	--	0.8665				0.8128	--
DENSITY, GMS/CC @ 75°F	0.8064	--	0.8612				0.8070	--
LIQ. RATE, CC/HR.	347.9	--	366.5				490.5	--
LHSV	0.88	--	0.93				1.24	--
TOTAL PRESS., PSIG	3000	3000.	1500.				1500.	1500.
TEMP., °F	700.	700.	700.				700.	700.
H_2 RATE, SCFH	11.91	--	10.68				13.38	--
H_2 RATE, SCF/BBL	5440.	--	4630.				4340.	--
FEED								
PARAFFINS							77.2	SITE AIR FAILURE
MONOCYCLOPARAFFINS		UNIT ON HOLD FOR FEED CHANGE						
DICYCLOPARAFFINS								
TRICYCLOPARAFFINS								
ALKYLBENZENES							22.5	UNIT ON HOLD
INDANES+TETRALINS								
INDENES								
NAPHTHALENES								
PPM S	361.		(0.82%)				286.	
PPM N			(1.37%)				30.	
PRODUCT	16 hr.		4 hr.	20 hr.	28 hr.	44 hr.	7.7 hr.	
PARAFFINS								
MONOCYCLOPARAFFINS	95.4		89.6	88.3	85.9	82.1		
DICYCLOPARAFFINS								
TRICYCLOPARAFFINS								
ALKYLBENZENES								
INDANES+TETRALINS								
INDENES	2.3		9.5	10.7	11.5	14.0		
NAPHTHALENES								
PPM S	1.		109.	5.	237.	4.		
PPM N	<30.		400.	<30.	100.	33.		

TABLE 4-1 (Cont'd)

RUN	13B	14B	15B	--	16B
START	1400 6/6/75	1330 6/9/75	1530 6/10/75	1530-6/14	1830 6/14/75
END	1330 6/9/75	1530 6/10/75	1530 6/14/75	1830-6/14	0830 6/18/75
RUN, HRS.	71.5	26.0	96.0	(3.0)	86.0
CUM. RUN HRS.	373.25	399.25	495.25	495.25	581.25
CUM. ELAPSED HRS.	650.50	676.50	772.50	775.5	861.50
FEED	JP-5	JP-5	JP-5	--	JP-5
START WT., LBS.	30.60	32.03	50.44	--	52.67
END WT., LBS.	15.30	25.82	37.34	--	40.35
TOTAL FEED, LBS.	15.30	6.21	13.10	--	12.32
TOTAL PROD. RECOVERED, LBS.	14.93	4.35	ADDED WITH 16B	--	24.05
RATE, LBS/HR.	0.214	0.239	0.136	--	0.143
RATE, GMS/HR.	97.1	108.3	61.9	--	65.0
DENSITY, GMS/CC @ 60°F	0.8128	0.8128	0.8128	--	0.8128
DENSITY, GMS/CC @ 75°F	0.8070	0.8070	0.8070	--	0.8070
LIQ. RATE, CC/HR.	120.3	134.2	76.7	--	80.5
LHSV	0.30	0.34	0.19	--	0.20
TOTAL PRESS., PSIG	1500.	3000.	3000.	3000.	3000.
TEMP., °F	675.	650.	650.	650.	650.
H_2 RATE, SCFH	4.96	10.44	6.18	6.0	6.18
H_2 RATE, SCF/BBL	6560.	12,360.	12,800.	--	12,200.
FEED					
PARAFFINS					
MONOCYCLOPARAFFINS	77.2	77.2	77.2		77.2
DICYCLOPARAFFINS				LIQ.	
TRICYCLOPARAFFINS				FEED	
ALKYLBENZENES				SUSPENDED	
INDANES+TETRALINS					
INDENES	22.5	22.5	22.5		22.5
NAPHTHALENES					
PPM S	286.	286.	286.		286.
PPM N	<30.	<30.	<30.		<30.
PRODUCT					
PARAFFINS					
MONOCYCLOPARAFFINS					
DICYCLOPARAFFINS					
TRICYCLOPARAFFINS					
ALKYLBENZENES					
INDANES+TETRALINS					
INDENES					
NAPHTHALENES					
PPM S					
PPM N					

TABLE 4-1 (Cont'd)

RUN	--	17B	18B	--	19B
START	0830-6/18	1030 6/18/75	1500 6/19/75	1000-6/20	1030 6/23/75
END	1030-6/18	1500 6/19/75	1000 6/20/75	1030-6/23	0600 6/24/75
RUN, HRS.	(2.0)	28.5	19.0	(72.5)	19.5
CUM. RUN HRS.	581.25	609.75	628.75	628.75	648.25
CUM. ELAPSED HRS.	863.50	892.00	911.00	983.50	1003.00
FEED	JP-5	TOSCO SHALE OIL	JP-5	UNIT	JP-5
START WT., LBS.	25.25	36.22	24.60	SHUT	18.30
END WT., LBS.	24.88	17.20	19.74	DOWN	14.68
TOTAL FEED, LBS.	0.37	19.00	4.86	TO	3.62
TOTAL PROD. RECOVERED, LBS.		17.00		PERMIT	0
RATE, LBS/HR.	0.185	0.67	0.256	MAINTENANCE	0.186
RATE, GMS/HR.	83.9	302.4	116.0	WORK	84.2
DENSITY, GMS/CC @ 60°F	0.8128	0.8237	0.8128	ON	0.8128
DENSITY, GMS/CC @ 75°F	0.8070	0.8180	0.8070	BUILDING	0.8070
LIQ. RATE, CC/HR.	104.0	369.7	143.8	ROOF	104.3
LHSV	0.26	0.93	0.36	FANS	0.26
TOTAL PRESS., PSIG	1500.	1500.	3000.	OVER	3000.
TEMP., °F	650.	700.	650.	WEEKEND	650.
H_2 RATE, SCFH	6.8	8.89	9.75		9.56
H_2 RATE, SCF/BBL	10,400.	3820.	10,780.		14,550.
FEED					
PARAFFINS					
MONOCYCLOPARAFFINS					
DICYCLOPARAFFINS	HOLDING		...		
TRICYCLOPARAFFINS	PERIOD		77.2		77.2
ALKYLBENZENES	WHILE				
INDANES+TETRALINS	LOWERING		22.5		22.5
INDENES	PRESSURE				
NAPHTHALENES	FOR				
PPM S	TOSCO		286.		286.
PPM N	RUN		<30.		<30.
PRODUCT					19.5 hrs.
PARAFFINS					
MONOCYCLOPARAFFINS					
DICYCLOPARAFFINS					
TRICYCLOPARAFFINS					13.
ALKYLBENZENES					
INDANES+TETRALINS					
INDENES					
NAPHTHALENES					
PPM S					
PPM N					

TABLE 4-1 (Cont'd)

RUN		20B	21B	22B	23B
START	0600-6/24	0915 6/24/75	1600 6/24/75	0900 6/25/75	1600 6/25/75
END	0915-6/24	1600 6/24/75	0900 6/25/75	1600 6/25/75	0830 6/26/75
RUN, HRS.	(3.25)	6.75	17.00	7.00	16.5
CUM. RUN HRS.	648.25	655.00	672.00	679.00	695.5
CUM. ELAPSED HRS.	1006.25	1013.00	1030.00	1037.00	1053.5
FEED		JP-5	JP-5	JP-5	JP-5
START WT., LBS.	H_2	14.23	30.02	27.70	18.92
END WT., LBS.	REGULATOR	9.13	28.00	18.92	15.30
TOTAL FEED, LBS.	MALFUNCTION	5.10	2.02	8.78	3.62
TOTAL PROD. RECOVERED, LBS.		4.72	1.90	7.60	3.83
RATE, LBS/HR.	UNIT	0.756	0.119	1.25	0.219
RATE, GMS/HR.	ON	342.7	53.9	568.9	99.5
DENSITY, GMS/CC @ 60°F	HOLD	0.8128	0.8128	0.8128	0.8128
DENSITY, GMS/CC @ 75°F		0.8070	0.8070	0.8070	0.8070
LIQ. RATE, CC/HR.		424.7	66.8	705.0	123.3
LHSV		1.07	0.17	1.78	0.31
TOTAL PRESS., PSIG		3000.	3000.	3000.	3000.
TEMP., °F		650.	650.	650.	650.
H_2 RATE, SCFH		9.05	10.59	9.09	11.36
H_2 RATE, SCF/BBL		3390.	25,200.	2050.	14,640.
FEED					
PARAFFINS					
MONOCYCLOPARAFFINS		77.2	77.2	77.2	77.2
DICYCLOPARAFFINS					
TRICYCLOPARAFFINS					
ALKYLBENZENES					
INDANES+TETRALINS					
INDENES		22.5	22.5	22.5	22.5
NAPHTHALENES					
PPM S		286.	286.	286.	286.
PPM N		<30.	<30.	<30.	<30.
PRODUCT		6.75 hrs.	16.5 hrs.		7.5 hrs.
PARAFFINS					
MONOCYCLOPARAFFINS					
DICYCLOPARAFFINS		1.	1.		
TRICYCLOPARAFFINS					
ALKYLBENZENES					
INDANES+TETRALINS					
INDENES					
NAPHTHALENES					
PPM S					
PPM N					

TABLE 4-1 (Cont'd)

RUN	24B	25B	--	26B		27B
START	0830 6/26/75	1600 6/26/75	1100 6/27	1000 7/7/75		0830 7/9/75
END	1600 6/26/75	1100 6/27/75	1000 7/7	0830 7/9/75		8530 7/10/7
RUN, HRS.	7.50	19.0	(239.0)	46.5		21.0
CUM. RUN HRS.	703.00	772.0	722.0	768.5		789.5
CUM. ELAPSED HRS.	1061.00	1080.0	1319.0	1365.5		1386.5
FEED	JP-5	JP-5		JP-5		JP-5
START WT., LBS.	43.00	23.50		34.42		19.68
END WT., LBS.	32.41	18.30		25.28		15.48
TOTAL FEED, LBS.	10.59	5.20	VACATION SHUTDOWN	9.14		4.20
TOTAL PROD. RECOVERED, LBS.	10.17	5.50		8.37		4.12
RATE, LBS/HR.	1.41	0.274		0.197		0.200
RATE, GMS/HR.	640.5	124.1		89.16		90.72
DENSITY, GMS/CC @ 60°F	0.8128	0.8128		0.8128		0.8128
DENSITY, GMS/CC @ 75°F	0.8070	0.8070		0.8070		0.8070
LIQ. RATE, CC/HR.	793.6	153.8		110.5		112.4
LHSV	2.00	0.39		0.28		0.28
TOTAL PRESS., PSIG	3000.	3000.		3000.		800.
TEMP., °F	650.	650.		700.		700.
H_2 RATE, SCFH	9.56	11.16		5.78		5.20
H_2 RATE, SCF/BBL	1920.	11,530.		8300.		7360.
FEED						
PARAFFINS				41.8		41.8
MONOCYCLOPARAFFINS	77.2	77.2		25.6		25.6
DICYCLOPARAFFINS				10.1		10.1
TRICYCLOPARAFFINS				4.0		4.0
ALKYLBENZENES				11.7		11.7
INDANES+TETRALINS	22.5	22.5		3.3		3.3
INDENES				0.2		0.2
NAPHTHALENES				2.8		2.8
PPM S	286.	286.		286.		286.
PPM N	<30.	<30.		55.		55.
PRODUCT		17 hrs.		22.5HR	46.5HR	21 HR
PARAFFINS				44.5	45.7	45.0
MONOCYCLOPARAFFINS				40.1	39.3	35.3
DICYCLOPARAFFINS				11.0	10.6	7.9
TRICYCLOPARAFFINS		<1.		3.2	3.5	3.2
ALKYLBENZENES				0.8	0.5	5.4
INDANES+TETRALINS				0.0	0.0	2.8
INDENES				0.0	0.0	0.0
NAPHTHALENES				0.1	0.2	0.1
PPM S				3.	1.	<1.
PPM N				3.3	25.	26.

TABLE 4-1 (Cont'd)

RUN	--	28B	29B	30B	--
START	0530 7/10	0800 7/10/75	1515 7/10/75	0930 7/11/75	1600 7/11
END	0800 7/10	1515 7/10/75	0930 7/11/75	1600 7/11/75	1030 7/14
RUN, HRS.	(2.5)	7.25	18.25	6.5	(66.5)
CUM. RUN HRS.	789.5	796.75	815.0	821.5	821.5
CUM. ELAPSED HRS.	1389.0	1396.25	1414.5	1421.0	1487.5
FEED		JP-5	JP-5	JP-5	
START WT., LBS.		15.48	35.55	21.70	
END WT., LBS.		14.02	21.70	15.07	
TOTAL FEED, LBS.		1.46	13.85	6.63	
TOTAL PROD. RECOVERED, LBS.		--	13.08	7.02	WEEKEND SHUT-
RATE, LBS/HR.	LOW HYDRO-	0.201	0.759	1.02	DOWN TO PERMIT
RATE, GMS/HR.	GEN FLOW	91.34	344.23	462.66	SUBSTATION
DENSITY, GMS/CC @ 60°F	SHUTDOWN	0.8128	0.8128	0.8128	REPAIRS
DENSITY, GMS/CC @ 75°F		0.8070	0.8070	0.8070	
LIQ. RATE, CC/HR.		113.2	426.6	573.3	
LHSV		0.29	1.08	1.45	
TOTAL PRESS., PSIG		800.	800.	800.	
TEMP., °F		700.	700.	700.	
H_2 RATE, SCFH		4.90	4.75	4.51	
H_2 RATE, SCF/BBL		6890.	1770.	1250.	
FEED					
PARAFFINS		41.8	41.8	41.8	
MONOCYCLOPARAFFINS		25.6	25.6	25.6	
DICYCLOPARAFFINS		10.1	10.1	10.1	
TRICYCLOPARAFFINS		4.0	4.0	4.0	
ALKYLBENZENES		11.7	11.7	11.7	
INDANES+TETRALINS		3.3	3.3	3.3	
INDENES		0.2	0.2	0.2	
NAPHTHALENES		2.8	2.8	2.8	
PPM S		286.	286.	286.	
PPM N		55.	55.	55.	
PRODUCT					
PARAFFINS					
MONOCYCLOPARAFFINS					
DICYCLOPARAFFINS					
TRICYCLOPARAFFINS					
ALKYLBENZENES					
INDANES+TETRALINS					
INDENES					
NAPHTHALENES					
PPM S					
PPM N					

TABLE 4-1 (Cont'd)

RUN	31B	--	32B	33B	--
START	1030 7/14/75	0030 7/15	1100 7/15/75	1230 7/16/75	1930 7/16
END	0030 7/15/75	1100 7/15	1230 7/16/75	1930 7/16/75	1030 7/21
RUN, HRS.	14.0	(10.5)	25.5	7.0	(111.0)
CUM. RUN HRS.	835.5	835.5	861.0	868.0	868.0
CUM. ELAPSED HRS.	1501.5	1512.0	1537.5	1544.5	1655.5
FEED	JP-5		JP-5	JP-5	
START WT., LBS.	14.95		31.62	36.70	
END WT., LBS.	12.82		10.80	31.15	
TOTAL FEED, LBS.	2.13		20.82	5.55	LOW HYDRO-GEN FLOW SHUTDOWN
TOTAL PROD. RECOVERED, LBS.	2.31		--	6.38	
RATE, LBS/HR.	0.152	LOW LIQUID FLOW SHUT-DOWN	0.816	0.793	
RATE, GMS/HR.	69.01		370.3	359.6	
DENSITY, GMS/CC @ 60°F	0.8128		0.8128	0.8128	--
DENSITY, GMS/CC @ 75°F	0.8070		0.8070	0.8070	
LIQ. RATE, CC/HR.	85.5		458.9	445.6	REACTOR RUPTURE DISC FAILURE & REPLACEMENT
LHSV	0.22		1.16	1.13	
TOTAL PRESS., PSIG	3000.		3000.	3000.	
TEMP., °F	700.		700.	700.	
H_2 RATE, SCFH	4.59		3.78	6.96	
H_2 RATE, SCF/BBL	8530.		1310.	2480.	
FEED					
PARAFFINS	41.8		41.8	41.8	
MONOCYCLOPARAFFINS	25.6		25.6	25.6	
DICYCLOPARAFFINS	10.1		10.1	10.1	
TRICYCLOPARAFFINS	4.0		4.0	4.0	
ALKYLBENZENES	11.7		11.7	11.7	
INDANES+TETRALINS	3.3		3.3	3.3	
INDENES	0.2		0.2	0.2	
NAPHTHALENES	2.8		2.8	2.8	
PPM S	286.		286.	286.	
PPM N	55.		55.	55.	
PRODUCT			21.5 HR		
PARAFFINS			43.5		
MONOCYCLOPARAFFINS			38.5		
DICYCLOPARAFFINS			12.7		
TRICYCLOPARAFFINS			4.2		
ALKYLBENZENES			0.6		
INDANES+TETRALINS			0.0		
INDENES			0.0		
NAPHTHALENES			0.2		
PPM S			<1.		
PPM N					

TABLE 4-1 (Cont'd)

RUN	34B	35B	36B	--	101
START	1030 7/21/75	0830 7/22/75	1530 7/22/75	0830 7/23	1600 7/31/75
END	0830 7/22/75	1530 7/22/75	0830 7/23/75		0800 8/5/75
RUN, HRS.	22.0	7.0	17.0		112.0
CUM. RUN HRS.	890.0	897.0	914.0		112.0
CUM. ELAPSED HRS.	1677.5	1684.5	1701.5		112.0
FEED	JP-5	JP-5	JP-5	UNIT SHUT-DOWN FOR CATALYST REPLACEMENT	JP5
START WT., LBS.	29.22	24.64	29.40		37.86
END WT., LBS.	24.64	18.70	28.40		15.55
TOTAL FEED, LBS.	4.58	5.94	1.00		22.31
TOTAL PROD. RECOVERED, LBS.	3.4	5.72	--		20.57
RATE, LBS/HR.	0.208	0.849	0.059		0.199
RATE, GMS/HR.	94.43	384.91	26.68		90.4
DENSITY, GMS/CC @ 60°F	0.8128	0.8128	0.8128		
DENSITY, GMS/CC @ 75°F	0.8070	0.8070	0.8070		0.807
LIQ. RATE, CC/HR.	117.0	477.0	33.1		112.0
LHSV	0.30	1.20	0.08		0.28
TOTAL PRESS., PSIG	3000.	3000.	3000.		3000
TEMP., °F	700.	700.	700.		650
H_2 RATE, SCFH	9.68	9.51	9.43		5.4
H_2 RATE, SCF/BBL	13150.	3170.	45350.		7660
FEED					
PARAFFINS	41.8	41.8	41.8		
MONOCYCLOPARAFFINS	25.6	25.6	25.6		
DICYCLOPARAFFINS	10.1	10.1	10.1		
TRICYCLOPARAFFINS	4.0	4.0	4.0		
ALKYLBENZENES	11.7	11.7	11.7		
INDANES+TETRALINS	3.3	3.3	3.3		
INDENES	0.2	0.2	0.2		
NAPHTHALENES	2.8	2.8	2.8		
PPM S	286.	286.	286.		
PPM N	55.	55.	55.		
PRODUCT	22 HR				
PARAFFINS	44.6				
MONOCYCLOPARAFFINS	38.2				
DICYCLOPARAFFINS	11.5				
TRICYCLOPARAFFINS	3.9				
ALKYLBENZENES	0.9				
INDANES+TETRALINS	0.3				
INDENES	0.0				
NAPHTHALENES	0.4				
PPM S	6.				
PPM N					

TABLE 4-1- (Cont'd)

RUN	102	103	104	--	105
START	0800 8/5/75	1300 8/5/75	0830 1230 8/6/75	1030 8/6/75	1615 8/6/75
END	1300 8/5/75	0830 8/6/75	1030 1615 8/6/75	1230 8/6/75	0645 8/7/75
RUN, HRS.	5.0	19.5	5.75	2	14.5
CUM. RUN HRS.	117.0	136.5	142.25	142.25	156.75
CUM. ELAPSED HRS.	117.0	136.5	142.25	144.25	158.75
FEED	JP5	Garrett	JP5	--	Synthoil
START WT., LBS.	15.55	34.50	27.67	--	35.88
END WT., LBS.	12.12	20.20	22.97	--	26.43
TOTAL FEED, LBS.	3.43	14.30	4.70	--	9.45
TOTAL PROD. RECOVERED, LBS.	3.64	14.10	4.48	--	9.39
RATE, LBS/HR.	0.766	0.733	0.817	--	0.65
RATE, GMS/HR.	347.0	332.9	371g	--	296
DENSITY, GMS/CC @ 60°F					
DENSITY, GMS/CC @ 75°F	0.807	0.851	0.807	--	0.921
LIQ. RATE, CC/HR.	430	391.2	460	--	322
LHSV	1.09	0.99	1.16	--	0.81
TOTAL PRESS., PSIG	1500	1500	1500	1400	1500
TEMP., °F	700	700	700	700-500	700
H_2 RATE, SCFH	10.7	9.3	11.76	--	9.54
H_2 RATE, SCF/BBL	4900	4440	5040	--	5120
FEED					
PARAFFINS		35.9			0.5
MONOCYCLOPARAFFINS		5.9			38.8
DICYCLOPARAFFINS		10.5			8.5
TRICYCLOPARAFFINS		8.4			0.0
ALKYLBENZENES		16.5			21.2
INDANES+TETRALINS		10.7			21.4
INDENES		4.1			7.7
NAPHTHALENES		7.6			1.6
PPM S		6300			1000
PPM N		10700			3000
PRODUCT					
PARAFFINS					
MONOCYCLOPARAFFINS					
DICYCLOPARAFFINS					
TRICYCLOPARAFFINS					
ALKYLBENZENES					
INDANES+TETRALINS					
INDENES					
NAPHTHALENES					
PPM S			380		
PPM N					

TABLE 4-1 (Cont'd)

RUN		106	107	108	--
START	0645 8/7/75	0900 8/7/75	1500 8/7/75	0930 8/8/75	1430 8/8
END	0900 8/7/75	1500 8/7/75	0930 8/8/75	1430 8/8/75	1500 9/2
RUN, HRS.	2.25	6.0	18.5	5	-
CUM. RUN HRS.	156.75	162.75	181.25	186.25	186.25
CUM. ELAPSED HRS.	161.0	167.0	185.5	190.5	791.00
FEED	--	JP5	Synthoil	JP5	
START WT., LBS.	--	23.97	32.32	24.97	
END WT., LBS.	--	19.19	18.15	22.70	Shut
TOTAL FEED, LBS.	--	4.78	14.17	2.27	Down
TOTAL PROD. RECOVERED, LBS.	--	4.54	14.03	2.56	To
RATE, LBS/HR.	--	0.80	0.766	0.454	Perform
RATE, GMS/HR.	--	362	347.7	206	JFTOT
DENSITY, GMS/CC @ 60°F	--	0.807	0.92	0.807	Testing
DENSITY, GMS/CC @ 75°F					
LIQ. RATE, CC/HR.	--	448	378	255	
LHSV	--	1.13	0.95	0.64	
TOTAL PRESS., PSIG	Atmos.	1500	1500	1500	
TEMP., °F	550	700	700	700	
H_2 RATE, SCFH	--	11.25	9.62	12.54	
H_2 RATE, SCF/BBL	--	4940	4400	9680	
FEED					
PARAFFINS			0.5		
MONOCYCLOPARAFFINS			38.8		
DICYCLOPARAFFINS			8.5		
TRICYCLOPARAFFINS			0.0		
ALKYLBENZENES			21.2		
INDANES+TETRALINS			21.4		
INDENES			7.7		
NAPHTHALENES			1.6		
PPM S			1000		
PPM N			3000		
PRODUCT					
PARAFFINS					
MONOCYCLOPARAFFINS					
DICYCLOPARAFFINS					
TRICYCLOPARAFFINS					
ALKYLBENZENES					
INDANES+TETRALINS					
INDENES					
NAPHTHALENES					
PPM S					
PPM N					

TABLE 4- 1 (Cont'd)

RUN	--	109	110	111	--
START	1500 9/2	1000 9/3/75	0930 9/4/75	1100 9/8/75	1000 9/9
END	1000 9/3	0930 9/4/75	1100 9/8/75	1000 9/9/75	1600 9/9
RUN, HRS.	-	23.5	97.5	23.0	-
CUM. RUN HRS.	186.25	209.75	307.25	330.25	930.25
CUM. ELAPSED HRS.	810.00	833.50	931.00	954.00	960.0
FEED		JP-5	JP-5	PARAHO SHALE OIL	
START WT., LBS.		20.28	46.82	36.66	
END WT., LBS.	Shut	15.80	28.44	18.05	Shut
TOTAL FEED, LBS.	Down	4.48	18.38	18.61	Down
TOTAL PROD. RECOVERED, LBS.	Due To	4.19	17.45	17.97	To
RATE, LBS/HR.	Low	0.191	0.189	0.809	Perform
RATE, GMS/HR.	Hydrogen	86.47	85.51	367.02	Maintenance
DENSITY, GMS/CC @ 60°F	Flow	0.8128	0.8128	0.8665	Work
DENSITY, GMS/CC @ 75°F		0.8070	0.8070	0.8612	
LIQ. RATE, CC/HR.		107.2	106.0	426.2	
LHSV		0.27	0.27	1.08	
TOTAL PRESS., PSIG		3000.	800.	800.	
TEMP., °F		700.	700.	700.	
H_2 RATE, SCFH		5.74	5.09	8.00	
H_2 RATE, SCF/BBL		8510.	7640.	2980.	
FEED					
PARAFFINS		41.8	41.8		
MONOCYCLOPARAFFINS		25.6	25.6		
DICYCLOPARAFFINS		10.1	10.1		
TRICYCLOPARAFFINS		4.0	4.0		
ALKYLBENZENES		11.7	11.7		
INDANES+TETRALINS		3.3	3.3		
INDENES		0.2	0.2		
NAPHTHALENES		2.8	2.8		
PPM S		286.	286.		
PPM N		30.	30.		
PRODUCT					
PARAFFINS					
MONOCYCLOPARAFFINS					
DICYCLOPARAFFINS					
TRICYCLOPARAFFINS					
ALKYLBENZENES					
INDANES+TETRALINS					
INDENES					
NAPHTHALENES					
PPM S					
PPM N					

TABLE 4-1 (Cont'd)

RUN	112	113	--	114	115
START	1600 9/9/75	1430 9/10/75	0700 9/11	0945 9/11/75	1600 9/11/75
END	1430 9/10/75	0700 9/11/75	0945 9/11	1600 9/11/75	1230 9/12/75
RUN, HRS.	22.5	16.5	-	6.25	20.5
CUM. RUN HRS.	352.75	369.25	369.25	375.5	396.0
CUM. ELAPSED HRS.	982.50	999.00	1001.75	1008.0	1028.5
FEED	JP-5	TOSCO SHALE OIL		JP-5	GARRETT SHALE OIL
START WT., LBS.	29.45	28.84		28.85	26.80
END WT., LBS.	11.32	14.70	Shut	24.58	12.80
TOTAL FEED, LBS.	18.13	14.14	Down	4.27	14.00
TOTAL PROD. RECOVERED, LBS.	19.80	12.79	Due	4.19	13.57
RATE, LBS/HR.	0.806	0.857	To	0.683	0.683
RATE, GMS/HR.	365.49	388.71	Low	309.89	309.77
DENSITY, GMS/CC @ 60°F	0.8128	0.8237	Hydrogen	0.8128	0.8565
DENSITY, GMS/CC @ 75°F	0.8070	0.8180	Flow	0.8070	0.8510
LIQ. RATE, CC/HR.	452.9	475.20		384.0	364.0
LHSV	1.14	1.20		0.97	0.91
TOTAL PRESS., PSIG	800.	800.		800.	800.
TEMP., °F	700.	700.		700.	700.
H_2 RATE, SCFH	9.84	8.16		9.60	9.75
H_2 RATE, SCF/BBL	3450.	2730		3970.	4250.
FEED					
PARAFFINS	41.8			41.8	
MONOCYCLOPARAFFINS	25.6			25.6	
DICYCLOPARAFFINS	10.1			10.1	
TRICYCLOPARAFFINS	4.0			4.0	
ALKYLBENZENES	11.7			11.7	
INDANES+TETRALINS	3.3			3.3	
INDENES	0.2			0.2	
NAPHTHALENES	2.8			2.8	
PPM S	286.			286.	
PPM N	30.			30.	
PRODUCT					
PARAFFINS					
MONOCYCLOPARAFFINS					
DICYCLOPARAFFINS					
TRICYCLOPARAFFINS					
ALKYLBENZENES					
INDANES+TETRALINS					
INDENES					
NAPHTHALENES					
PPM S					
PPM N					

TABLE 4-1 (Cont'd)

RUN	116	--	201	202	203
START	1230 9/12/75		0930 9/30/75	1500 10/2/75	0245 10/3/75
END	1615 9/12/75		1500 10/2/75	0245 10/3/75	1315 10/3/75
RUN, HRS.	3.75		53.5	11.75	10.50
CUM. RUN HRS.	399.75		53.5	65.25	75.75
CUM. ELAPSED HRS.	1032.25		53.5	65.25	75.75
FEED	JP-5		JP-5	Synthoil Coal Liq.	Synthoil Coal Liq.
START WT., LBS.	24.58		28.75	27.63	20.63
END WT., LBS.	21.73	Shut	18.66	20.63	12.67
TOTAL FEED, LBS.	2.85	Down	10.09	7.00	7.96
TOTAL PROD. RECOVERED, LBS.	2.53	To	9.62	6.28	7.62
RATE, LBS/HR.	0.76	Change	0.189	0.596	0.758
RATE, GMS/HR.	344.73	Catalyst	85.55	270.2	343.9
DENSITY, GMS/CC @ 60°F	0.8128	Type	0.8005	0.9262	0.9262
DENSITY, GMS/CC @ 75°F	0.8070		0.7947	0.9209	0.9209
LIQ. RATE, CC/HR.	427.2		107.7	293.4	373.4
LHSV	1.08		0.25	0.69	0.88
TOTAL PRESS., PSIG	800.		3000.	1500.	800.
TEMP., °F	700.		650.	700.	700.
H_2 RATE, SCFH	10.93		9.25	9.11	10.42
H_2 RATE, SCF/BBL	4070.		13,660.	4940.	4440.
FEED					
PARAFFINS	41.8				
MONOCYCLOPARAFFINS	25.6				
DICYCLOPARAFFINS	10.1				
TRICYCLOPARAFFINS	4.0				
ALKYLBENZENES	11.7				
INDANES+TETRALINS	3.3				
INDENES	0.2				
NAPHTHALENES	2.8				
PPM S	286.				
PPM N	30.				
PRODUCT					
PARAFFINS					
MONOCYCLOPARAFFINS					
DICYCLOPARAFFINS					
TRICYCLOPARAFFINS					
ALKYLBENZENES					
INDANES+TETRALINS					
INDENES					
NAPHTHALENES					
PPM S					
PPM N					

TABLE 4-1 (Cont'd)

RUN	204	---	205	206	---
START	1315 10/31/75	1630 10/3/75	1000 10/6/75	0830 10/7/75	0830 10/8/75
END	1630 10/3/75	1000 10/6/75	0830 10/7/75	0830 10/8/75	1230 10/20/75
RUN, HRS.	3.25		22.5	24.0	-
CUM. RUN HRS.	79.0	79.0	101.5	125.5	125.5
CUM. ELAPSED HRS.	79.0	144.5	167.0	191.0	483.0
FEED	JP-5	Unit	JP-5	JP-5	Unit
START WT., LBS.	17.56	Shut	39.00	23.64	Shut
END WT., LBS.	15.80	Down	23.64	18.96	Down
TOTAL FEED, LBS.	1.76	For	15.36	4.68	To
TOTAL PROD. RECOVERED,	1.81	Week-	14.20	4.45	Perform
RATE, LBS/HR.	0.542	End	0.683	0.195	Analytical
RATE, GMS/HR.	245.6		309.6	88.45	Work
DENSITY, GMS/CC @ 60°F	0.8005		0.8005	0.8005	
DENSITY, GMS/CC @ 75°F	0.7947		0.7947	0.7947	
LIQ. RATE, CC/HR.	309.0		389.6	111.3	
LHSV	0.73		0.91	0.26	
TOTAL PRESS., PSIG	800.		800.	800.	
TEMP., °F	700.		700.	700.	
H_2 RATE, SCFH	10.95		9.38	10.07	
H_2 RATE, SCF/BBL	5630.		3830.	14,380.	
FEED					
PARAFFINS					
MONOCYCLOPARAFFINS					
DICYCLOPARAFFINS					
TRICYCLOPARAFFINS					
ALKYLBENZENES					
INDANES+TETRALINS					
INDENES					
NAPHTHALENES					
PPM S					
PPM N					
PRODUCT					
PARAFFINS					
MONOCYCLOPARAFFINS					
DICYCLOPARAFFINS					
TRICYCLOPARAFFINS					
ALKYLBENZENES					
INDANES+TETRALINS					
INDENES					
NAPHTHALENES					
PPM S					
PPM N					

TABLE 4-1 (Cont'd)

RUN	207	208	209	210	211
START	1230 10/20/75	1100 10/21/75	0830 10/22/75	2000 10/22/75	0845 10/23/75
END	1100 10/21/75	0830 10/22/75	2000 10/22/75	0845 10/23/75	1000 10/23/75
RUN, HRS.	22.5	21.5	11.5	12.75	1.25
CUM. RUN HRS.	148.0	169.5	181.0	193.75	195.0
CUM. ELAPSED HRS.	505.5	527.0	538.5	551.25	552.5
FEED	JP-5	JP-5	H-Coal Liquid	JP-5	JP-5
START WT., LBS.	18.68	79.98	35.50	24.20	22.06
END WT., LBS.	15.64	14.16	26.80	22.06	21.32
TOTAL FEED, LBS.	3.04	15.82	8.70	2.14	0.74
TOTAL PROD. RECOVERED, LBS.	2.85	14.64	7.38	1.59	0.79
RATE, LBS/HR.	0.135	0.735	0.757	0.168	0.592
RATE, GMS/HR.	61.28	333.8	343.2	76.13	268.5
DENSITY, GMS/CC @ 60°F	0.8005	0.8005	0.8567	0.8005	0.8005
DENSITY, GMS/CC @ 75°F	0.7947	0.7947	0.8512	0.7947	0.7947
LIQ. RATE, CC/HR.	77.1	420.0	403.1	95.8	337.9
LHSV	0.18	0.99	0.95	0.22	0.79
TOTAL PRESS., PSIG	1500.	1500.	1500.	800.	800.
TEMP., °F	650.	700.	700.	700.	700.
H_2 RATE, SCFH	6.40	10.94	8.50	10.91	10.56
H_2 RATE, SCF/BBL	13,200.	4140.	3350.	18,120.	4970.
FEED					
PARAFFINS					
MONOCYCLOPARAFFINS					
DICYCLOPARAFFINS					
TRICYCLOPARAFFINS					
ALKYLBENZENES					
INDANES+TETRALINS					
INDENES					
NAPHTHALENES					
PPM S					
PPM N					
PRODUCT					
PARAFFINS					
MONOCYCLOPARAFFINS					
DICYCLOPARAFFINS					
TRICYCLOPARAFFINS					
ALKYLBENZENES					
INDANES+TETRALINS					
INDENES					
NAPHTHALENES					
PPM S					
PPM N					

TABLE 4-1 (Cont'd)

RUN	212	212	---	---	---
START	1000 10/23/75	1000 10/23/75	1600 10/23/75	1930 10/23/75	0830 10/24/75
END	1600 10/23/75	1600 10/23/75	1930 10/23/75	0830 10/24/75	1315 10/24/75
RUN, HRS.	6.0 (5.08)	6.0 (5.08)	3.5	-	-
CUM. RUN HRS.	201.0	201.0	204.5	204.5	204.50
CUM. ELAPSED HRS.	558.5	558.5	562.0	575.0	579.75
FEED	H-Coal Liquid	H-Coal Liquid	JP-5	-	JP-5
START WT., LBS.	26.55	26.55	Automatic	Unit	Unit
END WT., LBS.	22.77	22.77	Shut Down	Down	Shut
TOTAL FEED, LBS.	3.78	3.78	Due		Down
TOTAL PROD. RECOVERED, LBS.	2.90	2.90	Low		For
RATE, LBS/HR.	0.744	0.744	Inlet		Inspection
RATE, GMS/HR.	337.5	337.5	Flows		Due
DENSITY, GMS/CC @ 60°F	0.8567	0.8567			High
DENSITY, GMS/CC @ 75°F	0.8512	0.8512			Reactor
LIQ. RATE, CC/HR.	396.5	396.5			Pressure
LHSV	0.93	0.93			Drop
TOTAL PRESS., PSIG	800.	800.			
TEMP., °F	700.	700.			
H_2 RATE, SCFH	7.69	7.69			
H_2 RATE, SCF/BBL	3080.	3080.			
FEED					
PARAFFINS					
MONOCYCLOPARAFFINS					
DICYCLOPARAFFINS					
TRICYCLOPARAFFINS					
ALKYLBENZENES					
INDANES+TETRALINS					
INDENES					
NAPHTHALENES					
PPM S					
PPM N					
PRODUCT					
PARAFFINS					
MONOCYCLOPARAFFINS					
DICYCLOPARAFFINS					
TRICYCLOPARAFFINS					
ALKYLBENZENES					
INDANES+TETRALINS					
INDENES					
NAPHTHALENES					
PPM S					
PPM N					

TABLE 4-1 (Cont'd)

RUN	---	---	301	302	---
START	1315 10/24/75	1515 11/05/75	1545 11/06/75	0815 11/07/75	1600 11/07/75
END	1515 11/05/75	1545 11/06/75	0815 11/07/75	1600 11/07/75	1045 11/12/75
RUN, HRS.	---	---	16.50	7.75	---
CUM. RUN HRS.	204.50	204.50	221 00	228 75	228.75
CUM. ELAPSED HRS.	869.75	894.25	910 75	918.50	1033.25
FEED			JP-5	JP-5	
START WT., LBS.			19.90	16.47	
END WT., LBS.	Unit	Resulfiding	16.47	15.00	Unit
TOTAL FEED, LBS.	Down	Catalyst	3.43	1.47	Shut
TOTAL PROD. RECOVERED, LBS.	For	Charge	2.90	1.20	Down
RATE, LBS/HR.	Inspection		0.208	0.190	--
RATE, GMS/HR.			94.29	86.04	Holiday
DENSITY, GMS/CC @ 60°F			0.8005	0.8005	
DENSITY, GMS/CC @ 75°F			0.7947	0.7947	
LIQ. RATE, CC/HR.			118.7	108 3	
LHSV			0.28	0.25	
TOTAL PRESS., PSIG			1250.	3000.	
TEMP., °F			650.	700.	
H_2 RATE, SCFH			5.81	5.07	
H_2 RATE, SCF/BBL			7780.	7450.	
FEED					
PARAFFINS					
MONOCYCLOPARAFFINS					
DICYCLOPARAFFINS					
TRICYCLOPARAFFINS					
ALKYLBENZENES					
INDANES+TETRALINS					
INDENES					
NAPHTHALENES					
PPM S					
PPM N					
PRODUCT					
PARAFFINS					
MONOCYCLOPARAFFINS					
DICYCLOPARAFFINS					
TRICYCLOPARAFFINS					
ALKYLBENZENES					
INDANES+TETRALINS					
INDENES					
NAPHTHALENES					
PPM S					
PPM N					

TABLE 4-1 (Cont'd)

RUN	303	304	305
START	1045 11/12/75	0900 11/13/75	0100 11/14/75
END	0900 11/13/75	0100 11/14/75	1300 11/14/75
RUN, HRS.	22.25	16.00	12.00*
CUM. RUN HRS.	251.00	267.00	279 00
CUM. ELAPSED HRS.	1055.50	1071.50	1083.50
FEED	JP-5	H-Coal	JP-5
START WT., LBS.	53.70	36.80	16.15
END WT., LBS.	36.65	24.10	10.85
TOTAL FEED, LBS.	17.05	12.70	5.30
TOTAL PROD. RECOVERED, LBS.	15.86	10.20	5.00
RATE, LBS/HR.	0.766	0.794	0.623
RATE, GMS/HR.	347.6	360.0	282.8
DENSITY, GMS/CC @ 60°F	0.8005	0.8567	0.8005
DENSITY, GMS/CC @ 75°F	0.7947	0.8512	0.7947
LIQ. RATE, CC/HR.	437.4	423.0	355.9
LHSV	1.03	0.99	0.84
TOTAL PRESS., PSIG	800.	800.	800.
TEMP., °F	700.	700.	700.
H_2 RATE, SCFH	8.93	8.79	9.96
H_2 RATE, SCF/BBL	3250.	3305.	4450.
FEED			Unit Shut Down To Change Catalyst at Run Termination
PARAFFINS			
MONOCYCLOPARAFFINS			
DICYCLOPARAFFINS			
TRICYCLOPARAFFINS			
ALKYLBENZENES			
INDANES+TETRALINS			
INDENES			
NAPHTHALENES			
PPM S			
PPM N			
PRODUCT			
PARAFFINS			
MONOCYCLOPARAFFINS			
DICYCLOPARAFFINS			
TRICYCLOPARAFFINS			
ALKYLBENZENES			
INDANES+TETRALINS			
INDENES			
NAPHTHALENES			
PPM S			
PPM N			

*Rates Based on Initial 8.5 Hour Period

TABLE 4- 1 (Cont'd)

Run	401	--	402	403	404
Start	1500 - 1/21/76	1030 - 1/24	1630 - 1/26/76	1030 - 1/27/76	1500 - 1/27/76
End	1030 - 1/24/76	1630 - 1/26	1030 - 1/27/76	1500 - 1/27/76	0900 - 1/28/76
Elapsed, Hrs.	67.5	54.0	18.0	4.5	18.0
Cum. Elapsed, Hrs.	67.5	121.5	139.5	144.0	162.0
Run, Hrs.	67.5	--	18.0	4.5	18.0
Cum. Run, Hrs.	67.5	67.5	85.5	90.0	108.0
Feed	JP-5 Blend	--	JP-5 Blend	JP-5 Blend	Garrett A
Start Wt., Lbs.	81.81	Liq.	35.35	29.30	13.70
End Wt., Lbs.	58.06	Feed	29.30	27.78	7.30
Total Feed, Lbs.	23.75	Pump	6.05	1.52	6.40
Total Prod. Rcvd., Lbs.	21.00	Failure	5.51	1.81	5.50
Rate, Lbs./Hr.	0.352		0.336	0.338	0.356
Gms./Hr.	159.6		152.5	153.2	161.3
Density, Gms./cc @ 60°F	0.8005		0.8005	0.8005	0.8553
Gms./cc @ 75°F	0.7947		0.7947	0.7947	0.8499
Liq. Rate, cc/Hr.	200.8		191.8	192.8	189.8
LHSV	0.51		0.48	0.49	0.48
Total Press., psig	3000.0		3000.0	2200.0	2200.0
Temp., °F	650.0		650.0	700.0	700.0
H_2 Rate, SCFH	9.46		9.75	9.89	9.77
H_2 Rate, SCF/BBL.	7490.0		8080.0	8150.0	8190.0
Product Density GMS/cc @ 60°F	0.7978		0.7970	0.7970	0.8005

Mass. Spect.	401 Feed	401 Prod.	402 Feed	402 Prod.	403 Feed	403 Prod.	404 Feed	404 Prod.
Paraffins	42.8	43.5	42.8	43.5	42.8	43.3	35.4	27.4
Monocycloparaffins	36.9	41.8	36.9	39.9	36.9	39.8	7.8	33.3
Dicycloparaffins	10.1	10.7	10.1	11.5	10.1	11.6	10.2	11.8
Tricycloparaffins	3.1	2.7	3.1	3.5	3.1	3.8	8.1	2.4
Alkylbenzenes	5.2	0.9	5.2	0.8	5.2	0.9	17.7	3.8
Indans+Tetralins	1.5	0.0	1.5	0.1	1.5	0.1	9.6	1.0
Indenes	0.0	0.0	0.0	0.0	0.0	0.0	4.3	0.0
Naphthalenes	0.1	0.0	0.1	0.2	0.1	0.2	6.4	0.0
TOTAL	99.9	99.9	99.9	99.9	99.9	100.0	99.5	99.7

TABLE 4-1 (Cont'd)

Run	--	405	406	407	408
Start	0900 - 1/28	1230 - 1/28/76	0900 - 1/29/76	1430 - 1/29/76	1030 - 1/30/76
End	1230 - 1/28	0900 - 1/29/76	1430 - 1/29/76	1030 - 1/30/76	1630 - 1/30/76
Elapsed, Hrs.	3.5	20.5	5.5	20.0	6.0
Cum. Elapsed, Hrs.	165.5	186.0	191.5	211.5	217.5
Run, Hrs.	--	20.5	5.5	20.0	6.0
Cum. Run, Hrs.	108.0	128.5	134.0	154.0	160.0
Feed	--	Garrett B	Garrett B	Garrett C	Garrett C
Start Wt., Lbs.	Feed	17.30	10.90	19.03	12.57
End Wt., Lbs.	Switch	10.90	7.07	12.57	8.17
Total Feed, Lbs.		6.40	3.83	6.46	4.40
Total Prod. Rcvd., Lbs.		5.74	3.80	6.15	4.26
Rate, Lbs./Hr.		0.312	0.696	0.323	0.733
Gms./Hrs.		141.6	315.9	146.5	332.6
Density, Gms./cc @ 60°F		0.8662	0.8662	0.8678	0.8678
Gms./cc @ 75°F		0.8608	0.8608	0.8623	0.8623
Liq. Rate, cc/Hr.		164.5	366.9	169.9	385.8
LHSV		0.42	0.93	0.43	0.97
Total Press., psig		2200.0	2200.0	2200.0	2200.0
Temp., °F		700.0	700.0	700.0	700.0
H_2 Rate, SCFH		9.33	8.85	9.95	9.53
H_2 Rate, SCF/BBL.		9010.0	3840.0	9310.0	3930.0
Product Density GMS/cc @ 60°F		0.8066	0.8153	0.8152	0.8231

Mass. Spect.	405 Feed	405 Prod.	406 Feed	406 Prod.	407 Feed	407 Prod.	408 Feed	408 Prod.
Paraffins	36.8	48.1	36.8	48.4	37.1	48.5	37.1	47.3
Monocycloparaffins	3.5	31.0	3.5	23.8	0.0	27.2	0.0	20.3
Dicycloparaffins	11.4	12.0	11.4	9.3	14.0	11.1	14.0	9.5
Tricycloparaffins	10.5	3.2	10.5	2.7	11.7	3.6	11.7	3.3
Alkylbenzenes	15.6	4.0	15.6	8.2	15.9	5.7	15.9	8.9
Indans+Tetralins	9.4	1.2	9.4	6.4	9.2	3.1	9.2	8.2
Indenes	5.4	0.0	5.4	0.7	5.2	0.2	5.2	1.5
Naphthalenes	7.1	0.0	7.1	0.1	6.6	0.1	6.6	0.6
TOTAL	99.7	100.0	99.9	99.9	99.9	99.9	99.9	100.0

TABLE 4-1 (Cont'd)

Run	409		410		411		412		
Start	1630 - 1/30/76		0930 - 2/02/76		2400 - 2/02/76		1100 - 2/03/76		1530 - 2/03/76
End	0930 - 2/02/76		2400 - 2/02/76		1100 - 2/03/76		1530 - 2/03/76		2200 - 2/03/76
Elapsed, Hrs.	65.0		14.5		11.0		4.5		6.5
Cum. Elapsed, Hrs.	282.5		297.0		308.0		312.5		319.0
Run, Hrs.	65.0		14.5		11.0		4.5		--
Cum. Run, Hrs.	225.0		239.5		250.5		255.0		255.0
Feed	JP-5 BLEND		TOSCO A		TOSCO B		TOSCO B		--
Start Wt., Lbs.	35.50		13.25		20.20		16.17		
End Wt., Lbs.	26.50		7.40		16.17		12.83		
Total Feed, Lbs.	9.00		5.85		4.03		3.34		LIQUID
Total Prod. Rcvd., Lbs.	6.75		5.10		3.52		2.83		FLOW
Rate, Lbs./Hr.	0.138		0.403		0.366		0.742		CONTROL
Gms./Hr.	62.8		183.0		166.2		336.7		VALVE
Density, Gms./cc @ 60°F	0.8005		0.8253		0.8389		0.8389		FAILURE
Gms./cc @ 75°F	0.7947		0.8197		0.8333		0.8333		
Liq. Rate, cc/Hr.	79.02		223.3		199.4		404.0		
LHSV	0.20		0.56		0.50		1.02		
Total Press., psig	2200.		2200.		2200.		2200.		
Temp., °F	700.		700.		700.		700.		
H_2 Rate, SCFH	8.93		9.76		9.98		9.33		
H_2 Rate, SCF/BBL.	17,970.		6950.		7960.		3670.		
Product Density GMS/cc @ 60°F	0.7991		0.7817		0.7841		0.7905		
Mass. Spect.	Feed	Prod.	Feed	Prod.	Feed	Prod.	Feed	Prod.	
Paraffins	42.8	44.2	24.8	52.0	25.7	51.8	25.7	51.1	
Monocycloparaffins	36.9	39.1	29.2	34.6	23.6	32.8	23.6	28.1	
Dicycloparaffins	10.1	11.5	9.2	8.8	10.5	9.1	10.5	8.0	
Tricycloparaffins	3.1	3.3	6.6	2.2	7.9	2.4	7.9	2.5	
Alkylbenzenes	5.2	1.2	17.2	1.7	16.2	2.7	16.2	6.9	
Indans + Tetralins	1.5	0.3	7.7	0.4	8.4	0.7	8.4	2.9	
Indenes	0.0	0.0	2.8	0.0	4.1	0.0	4.1	0.2	
Naphthalenes	0.1	0.2	2.1	0.0	3.3	0.0	3.3	0.0	
TOTAL	99.7	99.9	99.9	99.7	100.0	99.5	100.0	99.7	

TABLE 4-1 (Cont'd)

Run	413	414	415	416	417
Start	2200 - 2/03/76	0800 - 2/04/76	1730 - 2/04/76	0830 - 2/05/76	2100 - 2/05/76
End	0800 - 2/04/76	1730 - 2/04/76	0830 - 2/05/76	2100 - 2/05/76	0330 - 2/06/76
Elapsed, Hrs.	10.0	9.5	15.0	12.5	6.5
Cum. Elapsed, Hrs.	329.0	338.5	353.5	366.0	372.5
Run, Hrs.	10.0	9.5	15.0	12.5	6.5
Cum. Run, Hrs.	265.0	274.5	289.5	302.0	308.5
Feed	PARAHO CUT 4	PARAHO CUT 4	GARRETT 103	SYNTHOIL 107	H-COAL
Start Wt., Lbs.	13.07	10.64	19.60	12.37	17.30
End Wt., Lbs.	10.64	7.30	13.70	7.30	(13.26)
Total Feed, Lbs.	2.43	3.34	5.90	5.07	3.10
Total Prod. Rcvd., Lbs.	2.80	3.34	5.48	4.96	3.04
Rate, Lbs./Hr.	0.243	0.352	0.393	0.406	0.477
Gms./Hr.	110.2	159.5	178.4	184.0	216.3
Density, Gms./cc @ 60°F	0.8094	0.8094	0.8052	0.8670	0.8567
Gms./cc @ 75°F	0.8037	0.8037	0.7993	0.8614	0.8512
Liq. Rate, cc/Hr.	137.1	198.42	223.2	213.6	254.1
LHSV	0.35	0.50	0.56	0.54	0.64
Total Press., psig	2200.	2200.	2200.	2200.	2200.
Temp., °F	700.	700.	700.	700.	700.
H_2 Rate, SCFH	11.01	10.69	10.28	9.88	9.48
H_2 Rate, SCF/BBL.	12,760.	8570.	7320.	7350.	5930.
Product Density GMS/cc @ 60°F	0.7976	0.7985	0.7968	0.8327	0.8317

Mass. Spect.	413 Feed	413 Prod.	414 Feed	414 Prod.	415 Feed	415 Prod.	416 Feed	416 Prod.	417 Feed	417 Prod.
Paraffins	44.0	47.7	44.0	46.5	48.3	48.0	3.4	15.9		4.6
Monocycloparaffins	28.2	35.1	28.2	39.9	24.0	38.9	38.4	54.5		70.5
Dicycloparaffins	9.9	12.6	9.9	11.5	13.6	10.9	18.2	22.7		18.4
Tricycloparaffins	1.2	2.0	1.2	1.0	1.6	1.0	8.0	4.9		3.2
Alkylbenzenes	7.7	1.5	7.7	0.7	7.9	0.7	11.6	1.1		2.1
Indans + Tetralins	8.7	0.7	8.7	0.2	4.1	0.2	16.4	0.3		0.6
Indenes	0.0	0.0	0.0	0.0	0.1	0.0	3.4	0.0		0.0
Naphthalenes	0.0	0.1	0.0	0.0	0.0	0.0	0.2	0.2		0.2
TOTAL	99.7	99.9	99.7	99.8	99.6	99.7	99.6	99.9		100.0

TABLE 4-1 (Cont'd)

Run	-	418	419	420	421
Start	0330 - 2/06/76	1130 - 2/06/76	1030 - 2/09/76	1800 - 2/09/76	0930 - 2/10/76
End	1130 - 2/06/76	1030 - 2/09/76	1800 - 2/09/76	0930 - 2/10/76	0100 - 2/11/76
Elapsed, Hrs.	8.0	71.0	7.5	15.5	15.5
Cum. Elapsed, Hrs.	380.5	451.5	459.0	474.5	490.0
Run, Hrs.	--	71.0	7.5	15.5	15.5
Cum. Run, Hrs.	308.5	379.5	387.0	402.5	418.0
Feed		JP-5 BLEND	H-COAL 212	JP-5 BLEND	JP-5 BLEND
Start Wt., Lbs.		55.17	15.43	21.70	16.48
End Wt., Lbs.	LIQUID	30.70	12.78	16.48	11.04
Total Feed, Lbs.	FEED	24.47	2.65	5.22	5.44
Total Prod. Rcvd., Lbs.	PUMP	23.66	2.48	4.85	
Rate, Lbs./Hr.	FAILURE	0.345	0.353	0.337	
Gms./Hr.		156.3	160.3	152.8	
Density, Gms./cc @ 60°F		0.8005	0.8337	0.8005	0.8005
Gms./cc @ 75°F		0.7947	0.8281	0.7947	0.7947
Liq. Rate, cc/Hr.		196.7	193.5	192.2	
LHSV		0.50	0.49	0.49	
Total Press., psig		2200.	2200.	2200.	3000.
Temp., °F		700.	700.	700.	700.
H_2 Rate, SCFH		10.05	10.09	10.78	
H_2 Rate, SCF/BBL.		8130.	8290.	8920.	
Product Density GMS/cc @ 60°F		0.7969	0.8070	0.7972	

Mass. Spect.	-	418 Feed	418 Prod.	419 Feed	419 Prod.	420 Feed	420 Prod.	421 Feed	421 Prod.
Paraffins		42.8	43.7	17.3	28.4	42.8	42.0	42.8	44.1
Monocycloparaffins		36.9	41.0	44.2	53.9	36.9	42.6	36.9	39.9
Dicycloparaffins		10.1	10.8	10.2	12.9	10.1	10.7	10.1	11.1
Tricycloparaffins		3.1	2.9	2.0	2.9	3.1	3.2	3.1	3.4
Alkylbenzenes		5.2	1.0	14.6	1.0	5.2	0.8	5.2	0.8
Indans + Tetralins		1.5	0.2	10.5	0.3	1.5	0.2	1.5	0.2
Indenes		0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0
Naphthalenes		0.1	0.0	0.4	0.2	0.1	0.0	0.1	0.1
TOTAL		99.7	99.9	100.0	99.9	99.7	99.9	99.7	100.0

In the second week of operation, liquid feed at low rates (∿ 100 cc/hr) was continued overnight on two occasions. The unit functioned extremely well, and the unit's liquid product receiving system was then slightly modified to permit unattended week-end operation.

Unattended week-end operation was then attempted, but the unit was found to have shutdown due to "high operating sandbath temperature" after about twelve hours of operation. It was later determined, however, that this condition had in fact not occurred. All recorder charts indicated proper isothermal conditions at the time of shut-down. The particular control circuit, thermocouples, and temperature indicator controller were checked and found to be operating normally.

The unit was restarted and ran continuously for over four days (over 100 hours) before another inadvertent shut-down occurred. The cause was again indicated to be high sandbath temperature, and again this conditior was found not to have occurred in fact. The controller was replaced, even though no fault could be found, and the unit was set again to operate unattended over a weekend. However, this operation was cancelled after consultation with the safety engineer.

The initial start-up safety inspection of this unit was performed on the basis that the unit would be attended while in operation. It was therefore necessary to reconvene the safety inspection team to consider unattended operation.

In this first sequence of operations, liquid flow was varied from about 80 cc/hr to about 750 cc/hr, hydrogen flow from about 5 SCFH to 18 SCFH, and temperature from 600°F to 800°F. Except for brief periods and the weekend shutdown, the reactor was at temperature for the better part of three weeks with continuous hydrogen and/or hydrogen-liquid feed. The sulfur content of product collected at 690°F and 100 cc/hr liquid flow was indicated to have been less than 1 ppm.

4.1.2 Initial Nickel Catalyst Operations (Hydrogenation Runs 1A-4A)

Following approval by the safety inspection team for unattended operation, the reactor catalyst charge was charged out with Cyanamid HDS-3A, an extruded nickel-molybdena catalyst on an alumina base which has been found effective for sulfur and nitrogen removal and for saturation of polyaromatics.

This catalyst charge was calcined in place and presulfided using 10% H_2S/90% H_2 gas according to procedures recommended by the catalyst vendor. A total of 396 cc, weighing 287.9 grams was charged to six tubular reactors, which, along with two empty preheat tubes, constituted our operating reactor system. The catalyst charge, in the form of 1/16-inch pellets, thus had an apparent density of 0.727 g/cm^3 or about 45.3 lb/ft^3.

During this period, the unit's pressure switches and controllers were reset to permit operation at a total pressure of 3000 psig. Operation at this higher pressure was desired initially to provide optimum catalytic activity maintenance in preparation for our first runs with Paraho shale oil.

At this point we decided to label runs with an "A" designation to signify the first catalyst sulfiding operation (see Table 4-1), "B" for the second sulfiding, and so on. Runs which were aborted, and in which no run samples were obtained, were given no designation.

Following presulfiding, the unit was started up on straight Jet A feed at 144 cm^3/h 650°F, 3000 psig, with 10 SCFH H_2 (0.36 LHSV; 11,000 SCF/BBL). These conditions were maintained for 28.5 hours (Run 1A), at which time a feed of Jet A which had been adulterated with small quantities of 2,5 dimethylthiophene, 2,4,6 trimethylpyridine, and 2,5 dimethylpyrrole was started into the unit at the same conditions (Run 2A). These run conditions were maintained for 23.5 hours.

The doctored liquid feed rate was increased to 300 cm^3/h, but this next run was aborted shortly after conditions were achieved due to failure of a high-pressure Heise gauge on the reactor outlet. Straight JP-5 was run into the unit at the same conditions while repair was effected.

Run 3A was started again with the doctored feed at 268 cm^3/h, 650°F, 3000 psig, and 9.7 SCFH H_2 (0.68 LHSV; 5700 SCF/BBL). These conditions were maintained for 6.5 hours, and feed was switched to straight JP-5 at a lower feed rate for the next run. However this next run was aborted due to failure of the liquid feed pump overnight while the unit was unattended.

Inspection of the liquid feed pump showed no apparent defect. The pump was reprimed and appeared to be in operating condition. Suction filter elements were replaced, although showing no contamination.

Run 4A was started with straight JP-5 at 275 cm^3/h, 670°F, 3000 psig, and 9.3 SCFH H_2 (0.70 LHSV and 5400 SCF/BBL). Although these conditions were maintained for seven hours, the liquid feed pump stopped functioning twice in this period (5 to 10 minutes each time).

Because of the oil pumping failures encountered, it was decided to re-sulfide the catalyst. An abridged sulfiding procedure was followed, taking 24.5 hours, using 10% H_2S/90% H_2 treat gas.

4.1.3 Resulfided Nickel Catalyst Operations (Hydrogenation Runs 1B-10B)

All run data sets are summared in Table 4-1.

Run 1B was started following the sulfiding operating using straight JP-5. This run was aborted, however, when the liquid feed pump failed after about three hours of operation. Again, no mechanical defect was found on inspection of the pump; and the run was restarted at 270 cm^3/h, 650°F, 3000 psig, and 10.4 SCFH H_2 (0.68 LHSV; 6000 SCF/BBL).

Run 1B was cut short after some seven hours, due again to failure of the liquid feed pump. It was therefore decided to remove the pump for complete disassembly.

Run 2B was started on May 27, 1975 using straight JP-5 at 127 cm^3/h, 650°F, 3000 psig, and 9.5 SCFH H_2 (0.32 LHSV; 11,900 SCF/BBL). These conditions were maintained for 30.5 hours, at which point the feed was switched to an adulterated JP-5 for Run 3B at 175 cm^3/h, 650°F, 3000 psig, and 10.8 SCFH H_2 (0.44 LHSV; 9800 SCF/BBL).

Run 3B was terminated after 7.5 hours due to shutdown caused by the low-liquid flow sensor. The set-point of this device is subject to some excursion, and the shutdown was considered spurious. The device was reset and Run 4B was started with the same feed as was used in Run 3B. Run 4B was run for 21.75 hours at 136 cm^3/h, 650°F, 3000 psig, and 9.7 SCFH H_2 (0.35 LHSV, 11, 200 SCF/BBL).

Run 5B was next run with straight JP-5 for 7.75 hours at 155 cm^3/h, 650°F., 3000 psig, and 9.6 SCFH H_2 (0.39 LHSV; 9800 SCF/BBL). These conditions were maintained for 7.75 hours, and the unit was swung to a feed comprising a blend of doctored product collected in previous runs for Run 6B. Run 6B ran for 64.25 hours (unattended weekend operation) at about 150 cm^3/h, 650°F, 3000 psig, and 9.2 SCFH H_2 (0.38 LHSV; 9700 SCF/BBL).

All of the preceding runs were made at low space velocity and high pressure in order to maintain catalyst activity preparatory to running Paraho shale oil. It was not intended that this "holding pattern" should extend into June, but delivery of the shale oil was delayed. However, the mechanical operation of the system was improved in the interim.

Run 7B was next made using as feed the same blend of hydrotreated products fed to previous Run 6B. Run 7B extended 7.5 hours at 144 cc/hr liquid feed rate, 700°F, 3000 psig, and 9.4 SCFH H_2 rate (0.36 LHSV and 10,400 SCF H_2/BBL).

Feed was switched to JP-5 turbine fuel for Run 8B (16.75 hours at 336 cc/hr, 700°F, 3000 psig, and 8.7 SCFH H_2; 0.85 LHSV and 4100 SCF H_2/BBL) and for Run 9B (7.5 hours at 349 cc/hr, 700°F, 3000 psig, and 11.2 SCFH H_2; 0.88 LHSV and 5100 SCF H_2/BBL).

Run 10B was made with JP-5 which had been doctored by the addition of trace quantities of dimethylthiophene, trimethylpyridine and dimethylpyrrole (19.0 hours at 348 cc/hr, 700°F, 3000 psig, and 11.9 SCFH H_2; 0.88 LHSV and 5400 SCF H_2/BBL). All of the sulfur in the feed (361 ppm) was removed at these conditions.

4.1.4 Initial (Paraho) Shale Oil Operation (Hydrogenation Runs 11B-16B)

Following Run 10B, unit pressure was dropped to 1500 psig. The feed fraction distilled from Paraho shale oil (see Section 3.3.7) was then fed to the unit in Run 11B, the first operation with "synthetic" feed, on June 4, 1975. Feed was continued for 46.0 hours at 367 cc/hr., 700°F, 1500 psig, and 10.7 SCFH H_2 (0.93 LHSV and 4600 SCF H_2/BBL). The distilled material fed to the unit analyzed 0.82 weight per cent

sulfur and 1.39 weight per cent total nitrogen. Sulfur was reduced to about 5 ppm and nitrogen to less than 30 ppm at these conditions, as shown in Table 4-1. The effect of dropping hydrogen flow to a very low rate (less than 1000 SCF/BBL) for one hour is shown in the sample obtained at the 28th hour of the run. Sulfur content of product increased to 237 ppm and nitrogen content increased to 100 ppm.

A total of 32 pounds of the Paraho feed was charged to this run. A total of 29.5 pounds of product was recovered from Run 11B. Some 18.6 pounds of this product was distilled in a laboratory distillation system capable of atmospheric--vacuum operation (see Section 4.2.2).

Feed was switched to straight JP-5 for the next Run 12B. Run 12B was cut short due to a general area compressed air failure. The unit was maintained on hold for a half hour, by which time air pressure had been restored.

Straight JP-5 was also run into the unit for Run 13B, a weekend run lasting 71.5 hours (120 cc/hr, 675°F, 1500 psig, and 5.0 SCFH H_2; 0.3 LHSV and 6500 SCF H_2/BBL). For Run 14B, unit pressure was increased to 3000 psig and unit temperature dropped to 650°F (26.0 hours at 134 cc/hr, and 10.4 SCFH H_2; 0.34 LHSV and 12,400 SCF H_2/BBL).

Run 15B extended 96.0 hours at 77 cc/hr, 650°F, 3000 psig, and 6.2 SCFH H_2 (0.19 LHSV and 12,800 SCF H_2/BBL). Liquid feed was suspended for three hours following this run to test the liquid feed pump, and Run 16B was next made at essentially the same conditions as for Run 15B (86.0 hours at 80 cc/hr, 650°F, 3000 psig, and 6.2 SCFH H_2 (0.2 LHSV and 12,200 SCF H_2/BBL).

4.1.5 Initial TOSCO Shale Oil Operation (Hydrogenation Runs 17B-36B)

Unit pressure was again lowered to 1500 psig following Run 16B in order to prepare for operation with feed derived from TOSCO shale oil. A kerosene fraction distilled from TOSCO shale oil (see Section 3.3.7) was then run into the unit for Run 17B on June 18, 1975. Operating conditions for Run 17B were chosen to be the same as those used for the Paraho shale oil in Run 11B. About 19.0 pounds of this material were hydrotreated over a 28.5 hour period (370 cc/hr, 700°F, 1500 psig, and 8.9 SCFH H_2; 0.93 LHSV and 3800 SCF H_2/BBL).

The hydrotreated product from Run 17B was distilled in a laboratory distillation system (see Section 4.3.2).

Unit pressure was again increased to 3000 psig and JP-5 was run in for Run 18B following (19.0 hours at 144 cc/hr, 650°F, 3000 psig, and 9.75 SCFH H_2; 0.36 LHSV and 10,800 SCF H_2/BBL). It was necessary at this point to shut down to permit maintenance work on the electrical transformers supplying the area. The unit had been operated continuously for 520 hours without any mechanical problems.

Runs 19B through 25B were all made at 3000 psig and 650°F with JP-5 turbine fuel feed during the week of June 23. Feed rate was varied up to 794 cc/hr (LHSV of 2.0). There was in this period a loss of hydrogen feed for 3 hours due to a malfunctioning hydrogen pressure regulator.

We had expected to receive additional feedstock from the Crude Assay Laboratory in Baytown during June but none was forthcoming due to operating difficulties there. Following the very long trouble-free operating period described above, the unit began also to be plagued with a succession of minor difficulties which cut severely into the operating factor.

Normally, operations with the commercial jet fuel feeds which were employed to keep the system up while we were awaiting delivery of the synthetic feedstocks from Baytown produced negligible pressure drop across the reactor at usual flow rates. Reactor pressure drop at flow rates equivalent to liquid hourly space velocities of about 0.3 was normally less than the 10 psi or so able to be distinguished by the unit's Heise gauges. Operations with these feeds at higher flow rates, at LHSV's of about 1.0, normally produced reactor pressure drops of less than 50 psi (at a total operating pressure of 3000 psig).

It was, however, observed during operations with both the Paraho and TOSCO feeds (operations at LHSV of 1.0 and 1500 psig total pressure), that pressure drop across the catalyst bed increased from a very low level to about 225 psig in both cases. Unfortunately, the quantity of available feedstock limited the Paraho run to 46.0 hours, and the TOSCO run to 28.5 hours. When feed was switched to JP-5 at the conclusion of the Paraho run (Run 11B), the pressure drop across the reactor quickly returned to the normal low level (from about 200 psi to virtually nil in about two hours). It was assumed that whatever had caused the high pressure drop was being dissolved or chemically modified and/or washed free by the "clean" feed.

Some 282 hours of operation with JP-5 feed succeeded the Paraho run before the TOSCO feed was available. Reactor pressure drop was normally low throughout this period. However, pressure drop quickly increased after TOSCO feed was introduced (Run 17B), and the pressure drop at the conclusion of that run slightly exceeded that observed at the conclusion of the Paraho run, even though the TOSCO run length was less than two-thirds that of the Paraho run. It was again observed that the reactor pressure drop quickly dropped to normal when feed was switched from the TOSCO shale oil to JP-5 after Run 17B.

Because of continued delay in the delivery of synthetic feedstock, the unit continued to be cperated on commercial JP-5 feed following the TOSCO run. The unit was started up on JP-5 feed for Run 26B following a one-week vacation shutdown on July 7, 1975. Run 26B extended 46.5 hours at 110 cc/hr liquid feed rate, 700°F, 3000 psig, and 5.8 SCFH H_2 (0.28 LHSV and 8300 SCF H_2/BBL). Reactor pressure drop and catalyst activity appeared to be normal following the long shut-down.

Unit operating pressure was next dropped to 800 psig for Run 27B (21.0 hours at 112 cc/hr, 700°F, 800 psig, and 5.2 SCFH H_2; 0.28 LHSV and 7360 SCF/BBL). Comparison of Runs 26B and 27B (see Table 4-1) would indicate that neither desulfurization nor denitrogenation rates were affected by the pressure decrease. However, the degree of saturation of product fell from 99.1 to 91.4 percent as a consequence.

The unit suffered an automatic low hydrogen flow shut-down near the end of Run 27B. The cause was not determined; all hardware appeared to be operating normally.

The unit was restarted on Run 28B at essentially the same conditions as for 27B (7.25 hours at 113 cc/hr, 700°F, 800 psig, and 4.9 SCFH H_2; 0.29 LHSV and 6890 SCF H_2/BBL). Liquid feed rate was increased for Run 29B following (18.25 hours at 427 cc/hr. 700°F, 800 psig, and 4.75 SCFH H_2 1.08 LHSV and 1770 SCF H_2/BBL). Liquid rate was increased further for Run 30B (6.5 hours at 573 cc/hr, 700°F, 800 psig, and 4.5 SCFH H_2; 1.45 LHSV and 1250 SCF H_2/BBL). The unit was shut-down for the weekend at the conclusion of Run 30B to permit changeout of transformers in the sub-station feeding the area in which the unit is located.

The unit was started up at 3000 psig following the weekend shut-down. Run 31B was made at a very low flow rate (14.0 hours at 69 cc/hr, 700°F, 3000 psig, and 4.6 SCFH H_2; 0.22 LHSV and 8530 SCF H_2/BBL). An automatic low liquid flow shut-down occurred during this run, due presumably to skirting the limit of sensitivity of the flow sensor.

Liquid flow rate was increased for Run 32B following (25.5 hours at 459 cc/hr, 700°F, 3000 psig and 3.8 SCFH H_2; 1.16 LHSV and 1310 SCF H_2/BBL). Run 33B was nearly identical, except that the hydrogen rate was doubled (7.0 hours at 446 cc/hr, 700°, 3000 psig and 7.0 SCFH H_2; 1.13 LHSV and 2480 SCF H_2/BBL).

Shortly after the next run was begun, a rupture disc on the reactor inlet failed, instantaneously depressuring the system. The unit was down for 111 hours following this incident, during which the disc was replaced and the system pressure tested. A low nitrogen flow was maintained throughout to exclude air from the reactor.

The unit was started up on Run 34B at "standard conditions" (22 hours at 117 cc/hr, 700°F, 3000 psig and 9.7 SCFH H_2; 0.3 LHSV and 13,150 SCF H_2/BBL). Operation appeared normal, except that product sulfur had increased to 6 ppm from the normal 1 ppm, and the degree of aromaticity of product had increased to 1.6 percent from the normal 0.7-0.8 percent. Pressure drop across the reactor was about 70 psi, up from nominal zero.

The liquid rate was increased for Run 35B (7 hours at 477 cc/hr, 700°F, 3000 psig, and 9.5 SCFH H_2; 1.2 LHSV and 3170 SCF H_2/BBL). Pressure drop across the reactor also increased, reaching the 650 psi level. The highest previously observed pressure drop was the 225 psi observed during the shale oil runs.

Run 36B was intended to be a run at about 0.3 LHSV, but the unit continued running at an extremely low liquid flow rate while unattended (17 hours at 33 cc/hr, 700°F, 3000 psig, and 9.4 SCFH H_2; 0.06 LHSV and 45,300 SCF H_2/BBL). When liquid rate was increased to about 100 cc/hr the next morning, unit total pressure dropped to 1500 psig. The reactor pressure drop was in excess of 650 psi at this point.

Because additional synthetic feedstock had just been received, it was decided to replace the catalyst bed before further operation. Accordingly, the unit was shut down, so that new catalyst could be charged to the system.

4.1.6 Initial Garrett Shale Oil and Synthoil Coal Liquid Operations (Hydrogenation Runs 101-108)

A new reactor tube bundle was installed with fresh American Cyanamid HDS 3A catalyst in a configuration that duplicates the one previously used. The flow configuration consisted of two empty reactor tubes used for preheat followed by 5 reactor tubes each filled with 66 cm^3 (48 g) of catalyst. Thus, the total catalyst volume used in calculations is 396 cm^3. The catalyst charge was calcined in air for about 21 hours from 280 to 700°F, and presulfided in 10% H_2S in H_2 for almost 24 hours from 350 to 700°F. The pressure drop through the reactor was on the order of 180 psi after calcining, and dropped rapidly to about 25 psi after sulfiding started.

A series of runs with JP-5 was begun to ascertain whether the new reactor behaved in a similar manner to the previous one. The runs with the new reactor were numbered starting with 101 to indicate the first run with the first catalyst replacement.

Run 101 extended 112 hours (112.0 hours at 112 cc/hr., 650°F, 3000 psig, and 5.4 SCFH H_2; 0.28 LHSV and 7660 SCF H_2/BBL) feeding JP-5. Unit pressure was dropped to 1500 psig for Run 102 following (5.0 hours at 430 cc/hr., 700°F, 1500 psig, and 10.7 SCFH H_2; 1.09 LHSV and 4900 SCF H_2/BBL) again feeding JP-5.

The feed fraction distilled from Garrett shale oil (see Section 3.3.7) was then run into the unit for Run 103 on August 5, 1975 at our normal severity conditions (19.5 hours at 391 cc/hr., 700°F, 1500 psig, and 9.3 SCFH H_2; 0.99 LHSV and 4440 SCF H_2/BBL).

Reactor pressure drop, which had been essentially nil at the start of Garrett Run 103, had increased to 150 psi at the end of the run.

JP-5 was run into the unit immediately following in Run 104 (5.75 hours at 460 cc/hr., 700°F, 1500 psig, and 11.76 SCFH H_2; 1.16 LHSV and 5040 SCF H_2/BBL). A failure of the site air supply occurred in the middle of this run, resulting in unit shutdown. Unit conditions were only slightly affected during the standby period, and the run was resumed when air pressure had been restored about 90 minutes later. Reactor pressure drop had decreased to about 40 psi by the end of Run 104.

A feed fraction distilled from Bureau of Mines Synthoil coal liquid (see Section 3.3.7) was then run into the unit for Run 105 following on August 6, 1975 (14.5 hours at 322 cc/hr., 700°F, 1500 psig, and 9.54 SCFH H_2; 0.81 LHSV and 5120 SCF H_2/BBL). This run was terminated automatically due to "low hydrogen flow" while the unit was unattended. It was not possible after the fact to determine the reactor pressure drop at shutdown, except to note that it was in excess of the 50 psi range of the ΔP recorder. Presumably, the reactor pressure drop had approached the total operating pressure, since the system and all controls were found to be operating normally when operations were resumed with JP-5 about two hours later. Oddly, reactor pressure drop was found to be near zero at that point. Run 106 extended six hours with the JP-5 feed (6.0 hours at 448 cc/hr., 700°F, 1500 psig, and 11.25 SCFH H_2; 1.13 LHSV and 4940 SCF H_2/BBL), and pressure drop remained nil throughout.

The slightly low LHSV obtained in Synthoil Run 105 (0.81 vs. desired 1.0) was a consequence of insufficient compensation for the higher density of the Synthoil feed fraction relative to that of JP-5, which material had been used to set the feed rate in preceding Run 104. A second Synthoil normal severity Run 107 was consequently made, closer to the desired base conditions (18.5 hours at 378 cc/hr., 700°F, 1500 psig, and 9.62 SCFH H_2; 0.95 LHSV and 4400 SCF H_2/BBL). Unexpectedly, significant differences in the respective hydrotreated products were observed. Also unexpectedly, there was no perceptible reactor pressure drop throughout Synthoil Run 107, nor during the JP-5 Run 108 which followed (5.0 hours at 255 cc/hr., 700°F, 1500 psig, and 12.54 SCFH H_2; 0.64 LHSV and 9680 SCF H_2/BBL).

The unit was shut down at this point for the duration of the month of August due to vacations, and to permit analytical testing of fuel blends so far prepared in the program.

4.1.7 Low Severity Shale Oil Operations (Hydrogenation Runs 109-116)

Following the extended shutdown period, the unit was started up on commercial JP-5 feed. An initial attempt to start Run 109 was aborted due to shut-down caused by low hydrogen flow. Run 109 finally extended 23.5 hours at 107 cc/hr. liquid feed rate, 700°F, 3000 psig, and 5.7 SCFH H_2 rate (0.27 LHSV and 8500 SCF H_2/BBL). Run 110 followed at 800 psig total pressure (97.5 hours at 106 cc/hr, 700°F, 800 psig, and 5.1 SCFH H_2; 0.27 LHSV and 7640 SCF H_2/BBL). Our objective in these runs was to assess catalyst activity following the extended shut down, and to prepare the unit for a sequence of low-severity (800 psig) hydrotreating operations with our shale liquids.

The same Paraho feed fraction which had been fed to normal-severity Run 11B was employed in the first low-severity Run 111 on September 8, 1975 (23.0 hours at 426 cc/hr., 700°F, 800 psig, and 8.0 SCFH H_2; 1.1 LHSV and 2980 SCF H_2/BBL). It was necessary to shut the unit down immediately following this run for a period of six hours to permit unrelated maintenance work to proceed in the area. The unit was then swung over to JP-5 feed for Run 112 (22.5 hours at 453 cc/hr., 700°F, 800 psig, and 9.8 SCFH H_2; 1.14 LHSV and 3450 SCF H_2/BBL).

Reactor pressure drop had increased from about 20 psi to about 45 psi during the low-severity Paraho Run 111. Subsequently, in Run 112, the pressure drop across the reactor had dropped to about 10 psi.

The same TOSCO shale oil feed fraction previously fed to normal-severity Run 17B was fed to a low-severity Run 113 on September 10, 1975 (16.5 hours at 475 cc/hour, 700°F, 800 psig, and 8.2 SCFH H_2; 1.20 LHSV and 2730 SCF H_2/BBL). The run was cut short due to inadvertent shut-down caused by low-flow indication. A reactor pressure drop of 240 psi was estimated at that point.

Commercial JP-5 feed was swung in, and the unit was operated manually for about six hours until the system appeared to be operating normally. Run 114 extended 6.25 hours (6.25 hours at 384 cc/hr., 700°F, 800 psig, and 9.6 SCFH H_2; 0.97 LHSV and 3970 SCF H_2/BBL).

The feed fraction derived from Garrett shale oil and previously fed to normal-severity Run 103 was next fed to low-severity Run 115 on September 11, 1975 (20.5 hours at 364 cc/hr., 700°F, 800 psig, and 9.8 SCFH H_2; 0.91 LHSV and 4250 SCF H_2/BBL). Reactor pressure drop increased to 575 psi during Run 115, although operations did not appear to be otherwise affected.

JP-5 was fed to the unit for Run 116 following to terminate this series (3.75 hours at 427 cc/hr., 700°F, 800 psig, and 10.9 SCFH H_2; 1.08 LHSV and 4070 SCF H_2/BBL).

It was desired that the Synthoil coal liquid be hydrotreated over a cobalt-molybdenum catalyst, rather than the nickel molybdenum used with the shale oils. Accordingly, the unit was shut down at this point to effect replacement of the Cyanamid HDS-3A with NALCO 477.

4.1.8 Low-Severity Coal Oil Operations (Hydrogenation Runs 201-305)

Nickel-molybdenum catalyst, which had been employed up to this time for our syncrude hydrotreating operations, was changed out with cobalt-molybdenum catalyst for testing with Synthoil coal liquid. The new reactor bundle duplicated the previous configuration, consisting of two empty preheat tubes, followed by six reaction tubes, each containing 71 cc (46 grams) of Nalcomo 477 catalyst. Thus, the total bulk catalyst volume for this bundle was 426 cc.

The new catalyst charge was calcined and sulfided in place following procedures identical with those employed previously for nickel-molybdenum. This catalyst charge exhibited negligible pressure drop throughout these operations.

The unit was started up on JP-5 in Run 201. The "200" run series was used to denote those runs made on the first batch of NALCO 477.

Run 201 extended 53.5 hours at 108 cc/hr. liquid feed rate, $650^{o}F$, 3000 psig, and 9.3 SCFH H_2 rate (0.25 LHSV and 13,660 SCF H_2/BBL).

Synthoil coal liquid, the first synthetic crude to be fed over this cobalt catalyst, was charged to the unit in Run 202 on October 2, 1975. Total operating pressure for Run 202 was 1500 psig (11.75 hours at 293 cc/hr., $700^{o}F$, 1500 psig, and 9.1 SCFH H_2; 0.69 LHSV and 4940 SCF H_2/BBL).

Conditions for Run 202 were targeted to be identical with those employed in our previous normal-severity Run 107. Note, however, that the desired LHSV of 1.0 was not achieved. There was insufficient feed available to correct the situation during Run 202, or to repeat that run. Unit pressure was dropped to 800 psig for the following low-severity run.

In Run 203 following at 800 psig, the Synthoil liquid feed rate was again adjusted upwardly, but that correction too was insufficient (10.5 hours at 373 cc/hr., $700^{o}F$, 800 psig, and 10.4 SCFH H_2; 0.88 LHSV and 4440 SCF H_2/BBL).

Liquid feed was switched to JP-5 at the termination of the Synthoil runs. Run 204 extended only 3.25 hours at 390 cc/hr. liquid rate, $700^{o}F$, 800 psig, and 10.95 SCFH H_2 rate (0.73 LHSV and 5630 SCF H_2/BBL) before the unit was shut down. Maintenance unrelated to the unit was performed in the area in which the unit is located during the weekend following, necessitating the shut down.

The unit was started up on JP-5 to displace whatever syncrude may have been in the system. Run 205 extended 22.5 hours at 390 cc/hr. liquid rate, $700^{o}F$, 800 psig, and 9.4 SCFH H_2 rate (0.91 LHSV and 3830 SCF H_2/BBL). Run 206, following, extended 24.0 hours at 111 cc/hr., $700^{o}F$, 800 psig, and 10.1 SCFH H_2 rate (0.26 LHSV and 14,380 SCF H_2/BBL).

At the conclusion of these operations, the unit was shut down to permit distillation and analytical backlogs to be worked off.

The unit was started up again late in the month to process H-Coal liquid, which had just been received via Wright-Patterson from Hydrocarbon Research Inc. The unit was started up on JP-5 in Run 207 (22.5 hours at 77 cc/hr., $650^{o}F$, 1500 psig, and 6.4 SCFH H_2; 0.18 LHSV and 13,200 SCF H_2/BBL). Run 208 followed, again feeding JP-5 (21.5 hours at 420 cc/hr., $700^{o}F$, 1500 psig, and 10.9 SCF H_2; 0.99 LHSV and 4140 SCF H_2/BBL).

H-Coal liquid was fed to the unit for the first time in Run 209 on October 22, 1975 at our normal-severity conditions (11.5 hours at 403 cc/hr., $700^{o}F$, 1500 psig, and 8.5 SCFH H_2 rate; 0.95 LHSV and 3350 SCF H_2/BBL). Pressure drop across the reactor catalyst bed increased rapidly about four hours after the commencement of H-Coal feed. Since the upstream pressure rose to 3200 psig, or about the pressure level at which the hydrogen feed system was being maintained at that time, it was decided to suspend gas flow, and shortly after, liquid flow, to the system in preparation for aborting the run. However, the reactor pressure drop quickly dissipated, and the flows were restarted.

Pressure drop again increased to some high level about four hours after this, but this "plug" self-corrected, and reactor pressure drop was essentially nil at the conclusion of the run.

Feed was switched to JP-5 for Run 210 following (12.75 hours at 95 cc/hr., $700^{o}F$, 800 psig, and 10.9 SCFH H_2 rate: 0.22 LHSV and 18,120 SCF H_2/BBL). Run 211 next was a transition period used to adjust feed rate for the succeeding H-Coal run (1.25 hours at 338 cc/hr., 700°F, 800 psig, and 10.6 SCFH H_2; 0.79 LHSV and 4970 SCF H_2/BBL).

H-Coal liquid was again fed to the unit in Run 212. Operation was too erratic for the product to be useful (6.0 hours at an overall rate of 397 cc/hr., $700^{o}F$, 800 psig, and 7.69 SCFH H_2; 0.93 LHSV and 3080 SCF H_2/BBL). The reactor pressure drop increased more rapidly after commencement of H-Coal feed in this run than in previous H-Coal Run 209. It took only about two hours for the upstream pressure to approach available delivery pressure. Thereafter a succession of stops and starts on gas and liquid feeds was made in an unsuccessful attempt to stabilize the reactor pressure drop. The operation was terminated at a point where pressure drop again approached 3000 psi, giving no indication that recovery was possible.

Feed was switched to JP-5 at this point, but only a very small quantity of liquid could be introduced and the unit automatically shut down 3.5 hours later while unattended.

The unit was restarted on the day shift some thirteen hours later, but reactor pressure drop with JP-5 rose quickly, and only a very low liquid flow resulted, so that the unit was shut down for inspection.

Following shut-down of the unit due to incurred high pressure drop across the reactor catalyst charge while attempting to process H-Coal liquid, the pressure drop problem was reviewed with in-house hydrotreating specialists and with outside catalyst vendors. One of our specialists, noting the particular reactor configuration we employ, recalled a pressure drop problem associated with the use of empty preheat tubes ahead of a catalytic reactor used to process highly olefinic petroleum feedstocks. In that case, dimerization was taking place at high rate in the low-temperature, noncatalytic portion of the system. Although our feed materials

all presumably are quite low in olefin content, so that the dimerization which was the cause of pressure build-up in the petroleum case should not occur, we decided to test the suggestion to remove the preheat tubes from our system.

Accordingly, the unit's reactor assembly was lowered, and the preheat tubes removed. Care was taken during these operations to minimize exposure (to the atmosphere) of the catalyst in the system.

Following reassembly and pressure-testing of the reactor, the catalyst charge was resulfided with a gas mixture containing 10 percent H_2S in hydrogen using a temperature schedule extending over twenty-four hours.

The unit was started up on JP-5 feed. Runs made with the resulfided NALCOMO 477 cobalt-molybdenum catalyst are designated as the "300" series.

Run 301 extended 16.5 hours at 119 cc/hr. liquid feed rate 650°F, 1250 psig, and 5.8 SCFH H_2 rate (0.28 LHSV and 7780 SCF H_2/BBL). A reactor pressure drop of 500 psi was evidenced within an hour of the start of liquid feed, but this pressure drop slowly dissipated. It was about 125 psi four hours after start-up, and was about 30 psi at the end of the run (16.5 hours). Note that this pressure drop may have been due to residual matter deposited on the catalyst prior to the shut-down for preheat tube removal.

Run 302 was a one-shift operation at 3000 psig made to determine whether pressure drop would be observed at the higher total pressure (7.75 hours at 108 cc/hr., 700°F, 3000 psig, and 5.1 SCFH H_2 rate; 0.25 LHSV and 7450 SCF H_2/BBL). No pressure drop (nominal 5-20 psi) was observed across the reactor during this run. The unit was shut down at the conclusion of this run, covering an extended four-day holiday period.

The unit was started up again on JP-5 in Run 303 (22.25 hours at 437 cc/hr., 700°F, 800 psig, and 8.9 SCFH H_2; 1.03 LHSV and 3250 SCF H_2/BBL). There was no indication of undue pressure drop throughout this run, which was made at the same high rate desired for the synthetic crude. The unit's Heise gauges indicated a reactor pressure drop of less than 5 psi throughout.

Accordingly, Run 304 was made with H-Coal liquid, attempting once again to complete the low-severity operation originally tried in Run 212. Run 304 extended 16.0 hours at 423 cc/hr. liquid feed rate, 700°F, 800 psig, and 8.8 SCFH H_2 rate (0.99 LHSV and 3305 SCF H_2/BBL).

Reactor pressure drop during Run 304 was nominally less than 10 psi for the first three hours of operation. It then began to climb in a sinusoidal fashion, increasing to about 40 psi, dropping to about 20 psi, increasing to about 90 psi, dropping to about 30 psi, etc., until the peak had reached about 400 psi in the seventh hour of operation. From that point on, pressure drop appeared to increase more or less steadily to the end of the run, at which point it stood at 2000 psi. That is, the upstream reactor pressure in the sixteenth hour of operation was about 2800 psig, and the downstream pressure was being controlled at 800 psig. Because of the regulation afforded by the system's pressure and flow controllers, there was no effect of this increasing reactor pressure drop on gas or liquid flow rates through the unit, although loss of control was near at the end.

The unit was switched to JP-5 feed for Run 305 (12.0 hours at 356 cc/hr., 700^{o}F, 800 psig, and 10.0 SCFH H_2; 0.84 LHSV and 4450 SCF H_2/BBL). Reactor pressure drop had decreased from 2000 psi to 750 psi 8.5 hours into the run (note that rates listed above are based on this initial 8.5 hour period). At this point, it was attempted to reintroduce H-Coal liquid into the system, but this was immediately accompanied by a sharp increase in the reactor pressure drop, such that the upstream pressure approached the settings on the gas and liquid supply systems; and only very low flows could be established without resetting control limits. The unit was shut down about three hours later, when the pressure drop gave no indication of dissipating, even with reintroduction of JP-5.

The cobalt-molybdenum catalyst employed in the low-severity hydrotreatment of coal liquids was removed from the reactor. Cause of the high pressure drop experienced with the H-Coal liquid was found to be "carbonized" segment of catalyst particles extending about three inches in length at one point of a reactor tube, which was about centered in the reaction tube bundle. There was no obvious cause for the formation of the plug, and it was not determined immediately whether the material causing the plug was primarily carbon, or was polymer, ash, or some other constituent of the H-Coal liquid.

4.1.9 High-Severity Operations Hydrogenation Runs 401-421)

The reactor was charged with Cyanamid HDS-3A nickel-molybdenum catalyst for the experimental high-severity hydrotreatment segment. The new reactor bundle comprised only the six catalyst-filled reaction tubes, in contrast with previous configurations which included, in addition, two empty preheat tubes. Each reaction tube contained 66 cc (47 grams) of HDS-3A catalyst, for a total bulk catalyst volume of 396 cc.

The new reactor bundle was installed and underwent a satisfactory pressure test. The catalyst charge was then calcined and sulfided in place using procedures identical with those employed previously for nickel-molybdenum catalysts. This catalyst charge exhibited neglible pressure drop throughout these operations.

Unfortunately, the reactor bundle was found to be leaking shortly after hydrogen at high pressure (3000 psig) was admitted, along with liquid feed, to begin the first run. Attempts to isolate and repair the leaking fittings without disassembling the reactor bundle were unsuccessful, and it proved necessary to break every system fitting and completely disassemble the bundle to clean or replace each seating surface.

The catalyst charge was resulfided and the first run, Run 401, was restarted. One week had elapsed in the interval due to the mechanical problems.

Runs in this high-severity hydrotreatment segment are numbered in the "400" series.

Run 401 extended 67.5 hours feeding a JP-5 blend at 200 cc/hour, 650°F, 3000 psig total pressure, and 9.5 SCFH H_2 rate (0.51 LHSV and 7490 SCF H_2/BBL). The JP-5 feed blend used in this series was a mixture of product collected from previous operations in which commercial JP-5 fuel had been used as feed. This feed blend contained 81 ppm sulfur, 24 ppm nitrogen, and had a density of 0.8005 at 60°F.

An automatic shut-down due to low liquid feed flow interrupted Run 401. The motor coupling of the liquid feed pump was found to have failed. Repairs held up operations two days.

The unit was restarted on Run 402, again feeding the JP-5 blend at conditions identical with those employed in Run 401 (18.0 hours at 192 cc/hr., 650°F, 3000 psig, and 9.8 SCFH H_2; 0.48 LHSV and 8080 SCF H_2/BBL).

In Run 403, the total pressure was dropped to 2200 psig and the reactor temperature was raised to 700°F (4.5 hours at 193 cc/hr., 700°F, 2200 psig, and 9.9 SCFH H_2; 0.49 LHSV and 8150 SCF H_2/BBL).

Additional Garrett whole shale oil was distilled at Linden, at the same conditions used at Baytown to separate our original feed fraction, in order to obtain additional feedstock for this segment of the program. This newly-separated feed had boiling characteristics nearly identical with those of the Garrett kerosene fraction delivered by Baytown, which had been used in the previous Garrett (Occidental) runs.

The Garrett feed for Run 404 comprised all material boiling up to about 563°F, and was designated Garrett A. Run 404 extended 18.0 hours at 190 cc/hr., 700°F, 2200 psig, and 9.8 SCFH H_2 rate (0.48 LHSV and 8190 SCF H_2/BBL).

Feed was then switched to a second Garrett kerosene fraction comprising all material boiling up to about 650°F, and designated Garrett B, for Run 405 (20.5 hours at 165 cc/hr., 700°F, 2200 psig, and 9.3 SCFH H_2; 0.42 LHSV and 9010 SCF H_2/BBL). This second feed fraction had likewise been specifically separated from the Garrett whole shale oil crude at Linden to facilitate assessment of the severity of hydrotreatment.

In Run 406 following, this same second feed fraction, Garrett B, was fed at 367 cc/hour (5.5 hours at 700°F, 2200 psig, and 8.9 SCFH H_2; 0.93 LHSV and 3840 SCF H_2/BBL).

For Run 407, feed was switched to a third Garrett feed fraction, comprising all material boiling up to 700°F, and designated Garrett C (20.0 hours at 170 cc/hr., 700°F, 2200 psig, and 9.9 SCFH H_2; 0.43 LHSV and 9310 SCF H_2/BBL). This same feed fraction was used for Run 408 at 386 cc/hr. (6.0 hours at 700°F, 220 psig, and 9.5 SCFH H_2; 0.97 LHSV and 3930 SCF H_2/BBL).

Run 409 was started feeding a JP-5 blend at 79 cc/hr., 700°F, 2200 psig total pressure, and 8.9 SCFH H_2 rate (0.20 LHSV and 17,970 SCF H_2/BBL). Note that the analysis of the product may be compared, for example, with that of product from Run 403, made at half the catalyst age.

For Run 410, feed was switched to a TOSCO shale oil having boiling characteristics identical with the TOSCO kerosene fraction previously employed in our program. That is, additional whole TOSCO shale oil crude had been distilled at Linden, at the same conditions originally employed at Baytown to separate our kerosene feed fraction, in order to collect additional feedstock for this segment of the program.

The feed for Run 410 comprised all TOSCO material boiling up to about 563°F, and was designated TOSCO A. Run 410 extended 14.5 hours at 223 cc/hr., 700°F, 2200 psig, and 9.8 SCFH H_2 rate (0.56 LHSV and 6950 SCF H_2/BBL).

The liquid feed was then switched to a second TOSCO fraction comprising all material boiling up to about 650°F, and designated TOSCO B, for Run 411 (11.0 hours at 199 cc/hr., 700°F, 2200 psig, and 9.9 SCFH H_2 rate; 0.50 LHSV and 7960 SCF H_2/BBL). This second liquid feed fraction had likewise been specifically separated from the TOSCO whole shale oil crude at Linden to facilitate assessment of the severity of hydrotreatment in this last phase of our experimental program.

In Run 412, this same second TOSCO feed fraction, TOSCO B, was fed at 404 cc/hr. (4.5 hours at 700°F, 2200 psig, and 9.3 SCFH H_2; 1.02 LHSV and 3670 SCF H_2/BBL). During Run 412, the automatic liquid flow control valve failed, cutting the run short. The valve was repaired within six hours, and the unit was started up on Paraho feed.

Unfortunately, unlike the case reported for Garrett shale oil, and for TOSCO shale oil, no additional Paraho whole crude shale oil remained of our original sample. However, sufficient Paraho once-through material previously hydrotreated in our normal-severity program (Run 11B), and blended to approximate a Jet A fuel, was on hand to serve as feed to this segment of our program.

Hence the liquid feed to Run 413 (10.0 hours at 137 cc/hr., 700°F, 2200 psig, and 11.0 SCFH H_2 rate; 0.35 LHSV and 12,760 SCF H_2/BBL) and to Run 414 (9.5 hours at 198 cc/hr., 700°F, 2200 psig, and 10.7 SCFH H_2; 0.50 LHSV and 8570 SCF H_2/BBL) consisted of material which had already been hydrotreated in our unit. This same situation obtained for the following Run 415, in which Jet A blended from hydrotreated product collected in Garrett Run 103 was used as feed (15 hours at 223 cc/hr., 700°F, 2200 psig, and 10.3 SCFH H_2 rate; 0.56 LHSV and 7320 SCF H_2/BBL), and in the next Run 416, in which Jet A blended from Synthoil Run 107 product was used as feed (12.5 hours at 214 cc/hr., 700°F, 2200 psig, and 9.9 SCFH H_2; 0.54 LHSV and 7350 SCF H_2/BBL).

In the case of the H-Coal liquid, we did, and do, still retain some of the original sample purchased from Hydrocarbon Research. However, this "atmospheric overhead" material has caused plugging problems in our system whenever we have previously attempted to feed it. Nevertheless, we decided to attempt to feed it again at the high-severity conditions in Run 417 (6.5 hours at 254 cc/hr., 700°F, 2200 psig, and 9.5 SCFH H_2; 0.64 LHSV and 5930 SCF H_2/BBL).

Mechanical problems with the unit associated with development of high reactor pressure drop, or plugging, occurred in this run also after about the same total quantity of H-Coal feed had been introduced to the unit as in the previous cases where difficulty had been encountered. The higher reactor pressure, lower space velocity, and absence of the empty preheat tubes from our reactor configuration had not altered the plugging effect previously observed with this material.

A leak developed at the liquid feed pump as a consequence of the manipulations attempted to circumvent the pressure drop problem, requiring minor repairs.

The unit was started up on JP-5 blend following repair of our liquid feed system in Run 418 (71.0 hours at 197 cc/hr., 700°F, 2200 psig, and 10.0 SCFH H_2; 0.50 LHSV and 8130 SCF H_2/BBL). Reactor pressure drop was erratic in this period, but settled out at a value of about 300 psig (normal ≡ zero).

A small quantity of previously hydrotreated H-Coal material from Run 212 was available, and this was next fed to the unit in Run 419 (7.5 hours at 194 cc/hr , 700°F, 2200 psig, and 10.0 SCFH H_2; 0.49 LHSV and 8290 SCF H_2/BBL). Pressure drop across the reactor did not change significantly during this run.

With the running of the H-coal material in Run 419, we considered this segment of the experimental phase complete. Liquid feed was switched to JP-5 blend for Run 420, primarily to observe reactor pressure drop, or to determine whether the indicated "plug" could be dissolved. Run 420 extended 15.5 hours at 192 cc/hr., 700°F, 2200 psig, and 10.8 SCFH H_2 rate (0.49 LHSV and 8920 SCF H_2/BBL). Pressure drop did not change significantly in this period.

Reactor pressure was increased to 3000 psig and a New Run 421 was designated (15.5 hours at about 200 cc/hr., 700°F, 3000 psig). This run terminated automatically, presumably due to low liquid feed caused by high reactor pressure drop. Unit operations were terminated at this point.

4.2 Paraho Shale Oil Hydrotreat Product Characterization

In the remainder of this section, results obtained in the characterization of the hydrotreated products from hydrogenation experiments with feedstocks derived from shale oil and coal are presented. Results are presented in sequence grouped by feedstock. Refer to the appropriate sub-section in Section III of this report for details regarding feedstock preparation, and to the appropriate sub-section in Section 4.1 above for details pertaining to unit operation and conditions for particular experiments.

4.2.1 Paraho Whole Hydrotreated Products

Feedstocks derived from Paraho shale oil were fed to four hydrogenation experiments. These experiments are summarized on Table 4-2. Note that the kerosene fraction distilled from the original whole shale oil sample was fed only to low-severity Run 111 and to normal-severity Run 11B. These two experiments depleted the available supply of this feedstock.

The feed used for high-severity Paraho Runs 413 and 414 was the synthetic Jet A fuel blend prepared from hydrotreated product recovered from normal-severity Run 11B. Hence the products from Runs 413 and 414 represent doubly-hydrotreated materials.

All of the Paraho hydrogenation experiments were performed over nickel-molybdenum (HDS-3A) catalyst.

Table 4-2 show ASTM distillation data, paraffin/aromatic compositions obtained by mass spectroscopy, densities, and total sulfur and nitrogen contents for the respective feeds and (whole) hydrotreated products.

4.2.2 Distillation of Whole Paraho Hydrotreated Products

The whole hydrotreated products from Runs 111, 11B, and 414 were distilled in a glass laboratory system capable of extended vacuum operation. Distillation data for these three operations are presented, respectively, in Tables 4-3 through 4-5.

TABLE 4-2

PARAHO SHALE OIL HYDROTREATMENT EXPERIMENTS

	KEROSENE FEED FRACTION	PRODUCT 111	PRODUCT 11B	FEED JETA-11B	PRODUCT 414	PRODUCT 413
TOTAL PRESSURE, PSIG	-	800	1500	-	2200	2200
LHSV	-	1.08	0.93	-	0.50	0.35
ASTM DISTILLATION						
IBP, °F	373	220	279	374	349	331
5 PER CENT	413	310	324	393	378	356
10	426	354	354	397	389	372
20	446	400	394	411	403	393
30	462	429	420	421	411	409
40	475	445	440	429	423	420
50	486	462	457	437	432	432
60	494	478	472	445	440	444
70	506	493	487	454	448	456
80	518	509	504	463	468	469
90	531	529	525	475	471	492
95	550	545	541	484	481	517
FBP	556	570	565	490	499	551
DENSITY, GMS/CC @60°F.	0.8241	0.8124	0.8053	0.8094	0.7985	0.7976
MASS SPECTROSCOPY						
PARAFFINS	33.2	47.5	-	44.0	46.5	47.7
MONOCYCLOPARAFFINS	4.6	21.0	-	28.2	39.9	37.9
DICYCLOPARAFFINS	11.3	5.5	-	9.9	11.5	11.1
TRICYCLOPARAFFINS	10.2	2.0	-	1.2	1.0	1.3
PARAFFINS, TOTAL	59.3	76.0	-	83.3	98.9	98.0
ALKYLBENZENES	18.4	11.5	-	7.7	0.7	1.2
INDANS	11.6	8.9	-	8.7	0.2	0.4
INDENES	5.0	0.2	-	0.0	0.0	0.0
NAPHTHALENES	5.2	2.9	-	0.0	0.0	0.0
AROMATICS, TOTAL	40.2	23.5	-	16.4	0.9	1.6
SULFUR, TOTAL, WT. PERCENT	0.8200	0.0002	0.0011	0.0004	-	< 0.0001
NITROGEN, TOTAL, WT. PERCENT	1.3700	0.1700	0.0067	0.0036	0.0040	0.0033

TABLE 4-3

DISTILLATION OF WHOLE PARAHO HYDROTREATED PRODUCT RUN 111 - LOW SEVERITY

Reflux Ratio	Operating Pressure, MM Hg	Stillpot Temp., °F	Corrected Vapor Temp., °F	Cut No.	Yield Wt. %	Yield Cum. Wt. %
3:1	760	380	130	Start	--	—
4:1	↑	420	270	1	5.0	5.0
↑	│	437	317	2	5.0	10.0
│	│	455	357	3	4.9	14.9
│	│	465	385	4	5.1	20.0
↓	↓	485	423	5	9.9	29.9
4:1	760	501	451	6	9.9	39.8
3:1	100	381	463	7	9.9	49.7
↑	↑	395	483	8	9.9	59.6
│	│	408	502	9	9.9	69.5
│	│	422	526	10	9.9	79.4
│	│	429	540	11	5.0	84.4
↓	↓	439	555	12	5.0	89.5
3:1	100	453	568	13	5.0	94.5
			Bottoms Recovered		5.0	99.5

TABLE 4-4

DISTILLATION OF WHOLE PARAHO HYDROTREATED PRODUCT
RUN 11 B - NORMAL SEVERITY

Reflux Ratio	Operating Pressure, MM Hg	Stillpot Temp., °F	Corrected Vapor Temp., °F	Cut No.	Yield Wt. %	Yield Cum. Wt. %
3:1	760	398	153		START	--
3:1	760	416	279	1	3.66	3.66
3:1	760	422	300	2	1.79	5.45
3:1	760	440	335	3	5:01	10.46
1.5:1	100	337	335	3A	0.47	10.93
3:1	100	414	510	4	62.83	73.76
2.5:1	100	432	540	5	9.99	83.75
2.5:1	100	450	565	6	9.02	92.77
				Bottoms Recovered	6.87	99.64

TABLE 4-5

DISTILLATION OF WHOLE PARAHO
HYDROTREATED PRODUCT
RUN 414 - HIGH SEVERITY

Reflux Ratio	Operating Pressure, MM Hg	Stillpot Temp., °F	Corrected Vapor Temp., °F	Cut No.	Yield Wt. %	Yield Cum. Wt. %
3:1	760	418	212	START	--	--
3:1	760	425	320	1	2.6	2.6
3:1	760	438	347	2	4.1	6.7
3:1	760	443	374	3	7.7	14.4
3:1	100	329	401	4	13.0	27.4
3:1	100	342	428	5	14.2	41.6
3:1	100	360	455	6	23.1	64.7
3:1	100	378	482	7	17.3	82.0
3:1	100	398	509	8	13.5	95.5
3:1	100	400	514	9	2.4	97.9
				Bottoms Recovered	1.4	99.3

The collected cuts from the respective product distillations were recombined to produced final fuel blends whose boiling characteristics approached those of specification fuels.

4.2.3 Synthetic Jet A Fuel Blends from Paraho Experiments

The recombination of distillation cuts to produce specification fuels involved trial-and-error procedures in each case, in that the objective, always, was to maximize final blend yield, or quantity, while holding within specifications. In general, only minor adjustment of the leading and trailing boiling components was required, or was attempted, since absolute quantities of materials were strictly limited.

In the case of Paraho, the absence of light ends in the original shale oil sample (see Section III) precluded the production of JP-4-type, wide-cut fuel blends using our procedures. Consequently, only Jet A-type, narrow-cut fuels were prepared from Paraho feeds. Table 4-6 shows the same kind of information for the final Jet A fuel blends as is shown on Table 4-2 for the respective whole products from which they were derived.

4.2.4 Paraho Whole Product and Fuel Blend Specifications

Although boiling specifications for most fuel blends were met, as a consequence of the distillation/recombination operations described above, other fuel specifications were not necessarily on target. A very much larger quantity of working fluid, and considerable additional time and money, would be required to repeat the trial-and-error fuel recombinations until all specifications were met.

On the other hand, inspection of the data obtained with our procedures will usually show whether a particular specification is virtually "in hand," if it has been missed, or whether it is outside the range absolutely. In Table 4-7 are shown specification inspections for the feed fraction, whole hydrotreated products, and final Jet A fuel blends prepared from the normal- and low-severity Paraho hydrogenation experiments. It is generally obvious that required specifications were met, or closely approached, by the fuel blend prepared from the normal-severity experiment, but was marginal, at best, in the low-severity case.

There was insufficient feed to, and product from, the high-severity experiments to enable us to obtain all of the inspection analyses for those runs. Consequently, available data for the high-severity operations are limited to those shown in Tables 4-2 and 4-6. However, it is considered axiomatic that, if specification fuels can be obtained via hydrotreatment at lower severity, the higher-severity product would almost certainly exhibit superior properties.

TABLE 4-6

SYNTHETIC JET A FUEL BLENDS FROM PARAHO HYDROTREATMENT EXPERIMENTS

RUN NUMBER	111	11B	414
TOTAL PRESSURE, PSIG	800	1500	2200
LHSV	1.08	0.93	0.50
ASTM DISTILLATION			
IBP, °F.	328	374	352
5 PER CENT	359	393	378
10	376	397	388
20	396	411	400
30	413	421	410
40	430	429	420
50	442	437	428
60	453	445	435
70	463	454	444
80	474	463	452
90	488	475	464
95	495	484	473
FBP	505	490	482
DENSITY, GMS/CC @ 60°F.	0.8157	0.8094	0.7978
MASS SPECTROSCOPY			
PARAFFINS	44.8	44.0	45.5
MONOCYCLOPARAFFINS	23.2	28.2	39.7
DICYCLOPARAFFINS	5.3	9.9	12.4
TRICYCLOPARAFFINS	1.5	1.2	1.1
PARAFFINS, TOTAL	74.8	83.3	98.7
ALKYLBENZENES	12.8	7.7	0.6
INDANS	9.7	8.7	0.3
INDENES	0.1	0.0	0.0
NAPHTHALENES	2.1	0.0	0.0
AROMATICS, TOTAL	24.7	16.4	0.9
SULFUR, TOTAL, WT. PERCENT	-	0.0004	< 0.0001
NITROGEN, TOTAL, WT. PERCENT	0.2400	0.0036	0.0032
JFTOT, SPUN TUBE DEPOSIT RATING, °F.	400	570	< 590

TABLE 4-7

JET A FROM PARAHO SHALE OIL
INSPECTIONS

	SPEC.	ASTM STANDARD	FEED	RUN 113 (1500) TOTAL PRODUCT	RUN 113 (1500) BLENDED FUEL	RUN 111 (800) TOTAL PRODUCT	RUN 111 (800) BLENDED FUEL
AROMATICS, FIA (VOL.%)	MAX. 20	D 1319	TOO DARK	11.2	15.3	19.2	21.2
OLEFINS, FIA (VOL.%)		D 1319	TOO DARK	6.8	1.8	1.4	1.3
AROMATICS, M.S. (WT.%)			40.2	-	16.4	23.5	24.7
BROMINE NO. (CG BR/GM)			< 0.05	-	0.31	0.55	0.17
ANILINE PT. (°F.)		D 611	TOO DARK	145.0	153.5	147.5	139.3
DISTILLATION (°F) INIT.	REPORT	D 86	373.	279.	374.	220.	328.
10%	MAX. 400	D 86	426.	354.	397.	354.	376.
20%			446.	394.	411.	400.	396.
50%	MAX. 450	D 86	486.	457.	437.	462.	442.
90%			531.	525.	475.	529.	488.
FINAL	MAX. 550	D 86	556.	565.	490.	570.	505.
RESIDUE (%)	MAX. 1.5	D 86	SOLID	2.0	1.6	1.8	1.5
LOSS (%)	MAX. 1.5	D 86	-	0.0	0.4	0.7	0.5
ELEMENTAL ANALYSIS							
CARBON (WT.%)			-	85.77	-	86.60	86.12
HYDROGEN (WT.%)			-	13.67	13.45	13.18	13.02
NITROGEN (WT.%)			1.37	0.0067	0.0024/0.0036	0.1700	0.24
SULFUR (WT.%)	MAX. 03	D 1266	0.82	0.0011	0.0004	0.0002	-
FLASH POINT (°F)	MIN. 105	D 93	172.	99.	151.	70.	132.
FREEZE POINT (°F)	MAX. -36	D 2386	TOO DARK	-16.6	-34.6	-13.	-31.
GRAVITY 60°F (°API)	39-51	D 287	31.7	44.2	43.3	42.7	42.0
SPEC. GRAVITY (60/60°F)	0.775-0.830	D 287	0.8670	0.8053	0.8094	0.8124	0.8157
SMOKE POINT (MM)	MIN. 25	D 1322	-	27.0	27.3	16.2	20.9
VISCOSITY, -30°F (CS)	MAX. 15	D 445	60.(EXT	12.(EXT)	12.4	-	17.2/GEL

4.3 TOSCO Shale Oil Hydrotreated Product Characterization

In this section are presented data for the results of the characterization of products from the hydrogenation experiments performed with feedstocks derived from TOSCO shale oil.

4.3.1 TOSCO Whole Hydrotreated Products

Feedstocks derived from TOSCO shale oil were fed to five hydrogenation experiments. These experiments are summarized on Table 4-8. The original kerosene fractions distilled from whole TOSCO shale oil at the Baytown Crude Assay Laboratory was fed to low-severity Run 113 and to normal-severity Run 17B. These two experiments depleted the quantity of distillate delivered by Baytown.

A small amount of the original TOSCO whole shale oil sample was recovered from Baytown. Additional feed having boiling characteristics essentially identical with those of the original feed was distilled from this material (labeled Feed TOSCO A), including all material in the original crude boiling up to 563°F. Feed TOSCO A was fed to high-severity Run 410 only.

A second distillate fraction was collected from the whole crude shale oil recovered from Baytown, which included all material in the crude boiling up to 650°F (labeled Feed TOSCO B). Feed TOSCO B was fed to high-severity Runs 411 and 412.

All of the TOSCO hydrogenation experiments were performed over nickel-molybdenum (HDS-3A) catalyst.

4.3.2 Distillation of TOSCO Whole Hydrotreated Products

The whole hydrotreated products from Runs 113, 17B, and 410 were distilled in a laboratory system capable of atmospheric/vacuum operation. Distillation data for these three operations are presented respectively, in Tables 4-9 through 4-11.

4.3.3 Synthetic JP-4 Fuel Blends from TOSCO Experiments

In the case of the TOSCO whole shale oil sample, sufficient light ends were present to permit production of both narrow- and wide-cut fuel blends. Table 4-12 summarizes data obtained for the final JP-4 wide-cut fuel blends.

There was insufficient product from the high-severity Runs 411 and 412 to permit preparation of final fuel blends in like manner. However, there is little question that acceptable narrow- and wide-cut fuels could not have been so prepared from both products, the wider boiling range of the feed notwithstanding.

TABLE 4-8

TOSCO SHALE OIL HYDROTREATMENT EXPERIMENTS

	WHOLE SHALE OIL	KEROSENE FEED FRACTION	PRODUCT 113	PRODUCT 17B	FEED TOSCO A	PRODUCT 410	FEED TOSCO B	PRODUCT 412	PRODUCT 411
RUN NO.									
TOTAL PRESSURE, PSIG	--	--	800	1500	--	2200	--	2200	2200
LHSV	--	--	1.20	0.93	--	0.56	--	1.02	0.50
ASTM DISTILLATION									
IBP	--	220	225	254	237	252	214	247	241
5 PERCENT	--	273	262	282	278	281	276	283	281
10	--	294	281	296	295	299	294	301	297
20	--	320	310	319	323	325	331	332	323
30	--	347	334	340	347	348	363	358	346
40	--	372	361	363	372	372	300	388	372
50	--	399	384	388	397	392	438	415	400
60	--	426	410	411	425	410	473	447	427
70	--	453	438	434	451	431	506	476	458
80	--	478	460	460	476	452	536	508	492
90	--	502	494	492	501	485	569	548	526
95	--	518	517	513	520	511	585	572	552
FBP	--	530	536	537	534	540	593	590	570
DENSITY, GMS/CC @60°F	0.9279	0.8247	0.7872	0.7814	0.8197	0.7817	0.8333	0.7905	0.7841
MASS SPECTROSCOPY									
PARAFFINS	3.7	25.8	50.3	51.8	24.8	52.0	25.7	51.1	51.8
MONOCYCLOPARAFFINS	0.0	28.3	24.0	29.7	29.2	34.6	23.6	28.1	32.8
DICYCLOPARAFFINS	34.7	9.3	4.9	8.6	9.2	8.8	10.5	8.0	9.1
TRICYCLOPARAFFINS	19.7	6.4	1.1	2.1	6.6	2.2	7.9	2.5	2.4
PARAFFINS, TOTAL	58.1	69.8	80.3	92.2	69.8	97.6	67.7	89.7	96.1
ALKYLBENZENES	11.0	17.0	12.7	5.7	17.2	1.7	16.2	6.9	2.7
INDANS	10.5	7.9	5.5	1.8	7.7	0.4	8.4	2.9	0.7
INDENES	7.7	2.7	1.1	0.0	2.8	0.0	4.1	0.2	0.0
NAPHTHALENES	12.2	2.3	0.0	0.0	2.1	0.0	3.3	0.0	0.0
AROMATICS, TOTAL	41.4	29.9	19.3	7.5	29.8	2.1	32.0	10.0	3.4
SULFUR, TOTAL WT. PERCENT	0.6700	0.7600	0.0022	0.0036	0.8300	0.0074	0.7800	0.0244	0.0120
NITROGEN, TOTAL WT. PERCENT	1.8500	0.8700	0.0200	0.0020	0.7800	0.0041	1.0300	0.0130	0.0051

TABLE 4-9

DISTILLATION OF WHOLE TOSCO
HYDROTREATED PRODUCT
RUN 113 - LOW SEVERITY

Reflux Ratio	Operating Pressure, MM Hg	Stillpot Temp., °F	Corrected Vapor Temp., °F	Cut No.	Yield Wt. %	Yield Cum. Wt. %
4:1	760	321	125	START	--	--
		340	231	1	5.0	5.0
		353	251	2	5.0	10.0
		370	274	3	5.0	15.0
		380	290	4	4.9	19.9
		403	324	5	9.8	29.7
		428	353	6	9.9	39.6
		452	383	7	9.9	49.5
4:1	760	463	401	8	4.9	54.4
3:1	100	343	420	9	5.0	59.4
		365	444	10	10.0	69.4
		385	478	11	10.0	79.4
		397	494	12	4.9	84.3
		411	512	13	5.0	89.3
3:1	100	429	542	14	5.0	94.4
				Bottoms Recovered	5.2	99.6

TABLE 4-10

DISTILLATION OF WHOLE TOSCO
HYDROTREATED PRODUCT
RUN 17 B - NORMAL SEVERITY

Reflux Ratio	Operating Pressure, MM Hg	Stillpot Temp., °F	Corrected Vapor Temp., °F	Cut No.	Yield Wt. %	Yield Cum. Wt. %
4:1	760	325	150	-	Start	-
4:1	760	338	237	1	4.4	4.4
4:1	760	365	275	2	8.9	13.3
4:1	760	380	295	3	5.4	18.7
5:1	760	387	300	4	2.5	21.2
5:1	760	403	323	5	7.0	28.2
5:1	760	413	335	6	4.2	32.4
4.5:1	760	426	353	7	5.6	38.0
4.5:1	100	320	385	8	9.9	47.9
4.5:1	100	339	411	9	9.8	57.7
4:1	100	380	463	10	19.4	77.1
3:1	100	404	500	11	10.4	87.5
4:1	100	411	510	12	2.0	89.5
3:1	100	435	540	13	5.3	94.8
3:1	100	437	547	14	0.9	95.7
			Bottoms Recovered		3.8	99.5

TABLE 4-11

DISTILLATION OF WHOLE TOSCO
HYDROTREATED PRODUCT
RUN 410 - HIGH SEVERITY

Reflux Ratio	Operating Pressure, MM Hg	Stillpot Temp., °F	Corrected Vapor Temp., °F	Cut No.	Yield Wt. %	Yield Cum. Wt. %
2:1	760	333	129	START	--	--
2:1	760	342	212	1	1.8	1.8
2:1	760	353	248	2	3.0	4.8
2:1	760	372	275	3	5.8	10.6
2:1	760	400	302	4	9.7	20.3
2:1	760	404	320	5	1.4	21.7
2:1	100	303	349	6	9.8	31.5
2:1	100	314	374	7	8.5	40.0
2:1	100	332	401	8	11.0	51.0
2:1	100	347	428	9	10.7	61.7
2:1	100	373	455	10	13.5	75.2
2:1	100	388	482	11	7.0	82.2
2:1	100	412	509	12	7.3	89.5
2:1	100	433	536	13	3.9	93.4
2:1	100	450	550	14	2.1	95.5
			Bottoms Recovered		3.1	98.6

TABLE 4-12

SYNTHETIC JP 4 (WIDE-CUT) AVIATION TURBINE FUEL BLENDS FROM TOSCO SHALE OIL

Run No.	113	17B	410
Total Pressure, PSIG	800	1500	2200
LHSV	1.20	0.93	0.56
ASTM Distillation			
IBP, °F.	231	231	252
5 Percent	245	248	274
10	254	262	283
20	270	281	298
30	290	295	311
40	306	310	329
50	322	325	347
60	341	350	367
70	364	376	388
80	389	407	409
90	426	439	434
95	452	462	454
FBP	471	478	469
Density, GMS/CC @ 60 °F	0.7682	0.7681	0.7728
Mass Spectroscopy			
Paraffins	50.6	50.3	49.3
Monocycloparaffins	29.5	34.3	41.4
Dicycloparaffins	2.1	5.6	5.7
Tricycloparaffins	0.2	0.9	0.8
PARAFFINS, Total	82.4	91.1	97.2
Alkylbenzenes	14.3	7.0	2.4
Indans	3.0	1.5	0.1
Indenes	0.0	0.0	0.0
Naphthalenes	0.0	0.0	0.0
AROMATICS, Total	17.3	8.5	2.5
Sulfur, Total Wt. Percent	0.0005	0.0003	0.0011
Nitrogen, Total Wt. Percent	0.0093	0.0062	0.0019
JETOT, Spun Tube Deposit Rating, °F	534	580	>515

4.3.4 Synthetic Jet A Fuel Blends from TOSCO Experiments

In Table 4-13 are summarized data obtained for the final Jet A narrow-cut fuel blends derived from TOSCO shale oil.

4.3.5 TOSCO Whole Product and JP-4 Fuel Blend Specifications

Specification inspections for the feed fraction, whole hydrotreated products, and final JP-4 fuel blends prepared from the normal- and low-severity TOSCO hydrogenation experiments are presented in Table 4-14.

Again, there was insufficient product from the high-severity Run 410 with which to prepare sufficient final fuel to permit inspection analysis in like manner. Available data for the high-severity final wide-cut fuel blend shown on Table 4-12, however, would indicate that this material would exhibit superior properties.

4.3.6 TOSCO Whole Product and Jet A Fuel Blend Specifications

In Table 4-15 are presented specification inspections for the feed fraction, whole hydrotreated products, and final Jet A narrow-cut fuel blends prepared from the normal- and low-severity TOSCO hydrogenation experiments. Note that the data for the feed fraction and whole hydrotreated products shown in this table are identical with those shown in preceding Table 4-14.

4.4 Garrett (Occidental) Shale Oil Hydrotreated Product Characterization

In this section are presented data for the results of the characterization of products derived from the hydrogenation experiments performed with feedstocks distilled from Garrett shale oil.

4.4.1 Garrett Whole Hydrotreated Products

Feedstocks distilled from Garrett shale oil were fed to eight hydrogenation experiments. These experiments are summarized in Table 4-16 Note that an analysis of the original whole shale oil sample is included in the table.

Again, the kerosene fraction distilled from the original whole shale oil was fed only to low-severity Run 115 and to normal-severity Run 103, which operations depleted the available supply of that feedstock. However, additional whole shale oil was later distilled in laboratory equipment to separate three additional hydrogenation feedstocks: Feed Garrett A included all material in the original crude boiling up to 563°F, and, as such, should have been essentially identical with the original kerosene feed fraction. Feed Garrett A was fed only to high-severity Run 404.

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EVALUATION OF METHODS TO PRODUCE AVIATION TURBINE FUELS FROM SY--ETC(U)
MAY 76 C D KALFADELIS F33615-74-C-2036
UNCLASSIFIED EXXON/GRU.2PEA.76 AFAPL-TR-75-10-VOL-2 NL

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TABLE 4-13

SYNTHETIC JET A (NARROW-CUT) AVIATION
TURBINE FUEL BLENDS FROM TOSCO SHALE OIL

Run No.	113	17B	410
Total Pressure, PSIG	800	1500	2200
LHSV	1.20	0.93	0.56
ASTM Distillation			
IBP, °F	338	342	329
5 Percent	358	355	353
10	368	369	364
20	382	384	378
30	399	396	392
40	415	410	404
50	431	423	419
60	447	440	432
70	461	457	445
80	475	472	460
90	493	490	478
95	503	504	490
FBP	511	512	501
Density, GMS/CC @ 60 °F	0.8050	0.7946	0.7930
Mass Spectroscopy			
Paraffins	48.8	50.8	50.6
Monocycloparaffins	22.9	26.3	35.4
Dicycloparaffins	5.4	11.1	9.9
Tricycloparaffins	1.1	2.7	1.1
PARAFFINS, Total	78.2	90.9	97.8
Alkylbenzenes	11.4	5.4	1.5
Indans	7.7	2.9	0.4
Indenes	0.0	0.2	0.0
Naphthalenes	2.3	0.3	0.0
AROMATICS, Total	21.4	8.8	1.9
Sulfur, Total Wt. Percent	0.0012	0.0009	0.0008
Nitrogen, Total Wt. Percent	0.0170	0.0063	0.0034
JFTOT, Spun Tube Deposit Rating, °F	{482}	688	>575

TABLE 4-14

JP 4 FROM TOSCO SHALE OIL
INSPECTIONS

	SPEC.	ASTM STANDARD	FEED	RUN 17B (1500) TOTAL PRODUCT	RUN 17B (1500) BLENDED FUEL	RUN 113 (800) TOTAL PRODUCT	RUN 113 (800) BLENDED FUEL
AROMATICS, FIA (VOL.%)	MAX. 25.0	D 1319	TOO DARK	5.4	3.4	15.2	11.3
OLEFINS, FIA (VOL.%)	MAX. 5.0	D 1319	TOO DARK	0.8	0.2	0.4	0.2
AROMATICS, M.S. (WT.%)			29.9	7.5	8.5	19.3	17.3
BROMINE NO. (CG BR/GM)			<0.05	0.14	0.15	0.30	0.31
ANILINE PT. (°F.)		D 611	84.3	157.7	148.0	145.0	106.5
DISTILLATION (°F.) INIT.	REPORT	D 86	220.	254.	231.	225.	231.
10%	REPORT	D 86	294.	296.	262.	281.	254.
20%	MAX. 290	D 86	320.	319.	281.	310.	270.
50%	MAX. 370	D 86	399.	388.	325.	384.	322.
90%	MAX. 470	D 86	502.	492.	439.	494.	426.
FINAL	REPORT	D 86	530.	537.	478.	536.	471.
RESIDUE (%)	MAX. 1.5	D 86	1.0	1.7	1.8	2.0	1.5
LOSS (%)	MAX. 1.5	D 86	0.0	0.3	0.7	0.0	0.5
ELEMENTAL ANALYSIS							
CARBON (WT.%)			-	-	-	85.83	85.77
HYDROGEN (WT.%)			13.1	14.6	14.25	13.89	13.05
NITROGEN (WT.%)			0.8700	0.0020	0.0062	0.0200	0.0093
SULFUR (WT.)	MAX. 0.40	D 1266	0.7600	0.0036	0.0003	0.0022	0.0005
FLASH POINT		D 93	~66.	76.	~ 60.	64.	~ 75.
FREEZE POINT	MAX. -72	D 2386	TOO DARK	-34.6	-69.7	-34.6	-76.
GRAVITY 60°F (°API)	45-57	D 287	40.1	49.6	52.7	48.2	52.7
SPEC. GRAVITY (60/60°F)	.8 OZ-.751	D 287	0.8247	0.7814	0.7681	0.7872	0.7682
SMOKE POINT (MM)		D 1322	-	35.4	37.1	25.6	29.9
VISCOSITY, -30°F (CS)		D 445	5.7(EXT)	5.9	3.4	5.6	3.3

TABLE 4-15

JET A FROM TOSCO SHALE OIL - INSPECTIONS

	SPEC.	ASTM STANDARD	FEED	RUN 17B (1500) TOTAL PRODUCT	RUN 17B (1500) BLENDED FUEL	RUN 113 (800) TOTAL PRODUCT	RUN 113 (800) BLENDED FUEL
AROMATICS, FIA (VOL. %)	MAX. 20	D 1319	TOO DARK	5.4	5.4	15.2	18.6
OLEFINS, FIA (VOL. %)		D 1319	TOO DARK	0.8	1.3	0.4	0.4
AROMATICS, M.S. (WT. %)			29.9	7.5	8.8	19.3	21.4
BROMINE NO. (CG BR/GM)			<0.05	0.14	0.16	0.30	0.39
ANILINE PT. (°F)		D 611	84.3	157.7	161.5	145.0	147.9
DISTILLATION (°F) INIT.	REPORT	D 86	220.	254.	342.	225.	338.
10%	MAX. 400	D 86	294.	296.	369.	281.	368.
20%			320.	319.	384.	310.	382.
50%	MAX. 450	D 86	399.	388.	423.	384.	431.
90%			502.	492.	490.	494.	493.
FINAL	MAX. 550	D 86	530.	537.	512.	536.	511.
RESIDUE (%)	MAX. 1.5	D 86	1.0	1.7	1.7	2.0	1.5
LOSS (%)	MAX. 1.5	D 86	0.0	0.3	0.3	0.0	0.5
ELEMENTAL ANALYSIS							
CARBON (WT. %)			---	---	85.96	85.83	85.63
HYDROGEN (WT. %)			13.1	14.6	13.87	13.89	13.41
NITROGEN (WT. %)			0.8700	0.0020	0.0063	0.0200	0.0170
SULFUR (WT. %)	MAX. 0.3	D 1266	0.7600	0.0036	0.0009	0.0022	0.0012
FLASH POINT	MIN. 105	D 93	∿66.	76.	138.	64.	136.
FREEZE POINT	MAX. -36	D 2386	TOO DARK	-34.6	-29.2	-34.6	-29.2
GRAVITY 60 °F (°API)	39-51	D 287	40.1	49.6	46.6	48.2	44.3
SPEC. GRAVITY (60/60°F)	0.775-0.830	D 287	0.8247	0.7814	0.7946	0.7872	0.8050
SMOKE POINT (MM)	MIN. 25	D 1322	---	35.4	34.0	25.6	24.9
VISCOSITY, -30°F (CS)	MAX. 15	D 445	5.7(EXT)	5.9	9.6	5.6	GEL

TABLE 4-16

GARRETT SHALE OIL HYDROTREATMENT EXPERIMENTS

	WHOLE SHALE OIL	KEROSENE FEED FRACTION	PRODUCT 115	PRODUCT 103	FEED GARRETT A	PRODUCT 404	FEED GARRETT B	PRODUCT 405	PRODUCT 406	FEED GARRETT C	PRODUCT 407	PRODUCT 408	FEED GARRETT 103	PRODUCT 415
Total Pressure, PSIG	--	--	800	1500	--	2200	—	2200	2200	—	2200	2200	--	2200
LHSV	—	--	0.91	0.99	--	0.48	—	0.42	0.93	--	0.43	0.97	--	0.56
ASTM Distillation														
IBP	--	311	305	253	321	299	340	295	295	335	300	294	345	337
5 Percent	--	385	345	315	373	338	396	337	342	388	351	351	369	368
10	—	404	370	346	398	357	429	362	371	416	382	391	383	383
20	—	434	402	382	427	385	460	399	415	452	427	437	399	401
30	--	450	423	408	444	405	481	425	444	477	456	465	415	414
40	—	461	439	426	459	422	492	446	465	497	476	488	429	424
50	—	469	452	442	472	436	514	464	482	518	498	509	439	435
60	—	478	464	453	484	451	530	485	502	536	519	530	448	443
70	—	487	474	465	456	465	546	504	522	556	540	552	459	452
80	—	496	487	479	508	483	563	529	545	580	565	575	469	464
90	—	510	503	497	524	509	586	560	572	606	594	601	484	479
95	--	522	516	511	540	528	605	581	593	631	615	620	493	491
FBP	--	527	535	528	551	542	616	590	610	640	630	632	502	502
Density, GMS/CC @ 60°F	0.9042	0.8565	0.8133	0.8010	0.8553	0.8005	0.8662	0.8066	0.8153	0.8678	0.8152	0.8231	0.8052	0.7968
Mass Spectroscopy														
Paraffins	2.1	35.9	47.1	48.3	35.4	47.4	36.8	48.1	48.4	37.1	48.5	47.3	48.3	48.0
Monocycloparaffins	0.0	5.9	22.2	24.0	7.8	33.3	3.5	31.0	23.8	0.0	27.2	20.3	24.0	38.9
Dicycloparaffins	27.2	10.5	7.1	13.6	10.2	11.8	11.4	12.0	9.3	14.0	11.1	9.5	13.6	10.9
Tricycloparaffins	12.1	8.4	1.7	1.6	8.1	2.4	10.5	3.2	2.7	11.7	3.6	3.6	1.6	1.0
PARAFFINS, Total	41.4	60.7	78.1	87.5	61.5	94.4	62.2	94.3	84.2	62.8	90.4	80.4	87.6	98.8
Alkylbenzenes	18.8	16.5	11.9	7.9	17.7	3.8	15.6	4.0	8.2	15.9	5.7	8.9	7.9	0.7
Indans	15.5	10.7	8.9	4.1	9.6	1.0	9.4	1.2	6.4	9.2	3.1	8.2	4.1	0.2
Indenes	6.7	4.1	0.1	0.1	4.3	---	5.4	---	0.7	5.2	0.2	1.5	0.1	0.0
Naphthalenes	17.2	7.6	0.6	0.0	6.4	---	7.1	---	0.1	6.6	0.1	0.6	0.0	0.0
AROMATICS, Total	58.2	38.9	21.5	12.1	38.0	4.8	37.5	5.2	14.5	36.9	9.1	19.2	12.1	0.9
Sulfur, Total Wt. Percent	0.6400	0.6300	0.0049	0.0051	0.7000	0.0033	0.6000	0.0112	0.0014	0.7500	0.0149	0.0215	0.0004	<0.0001
Nitrogen, Total Wt. Percent	1.3000	1.0700	0.0042	0.0074	1.0200	0.0055	1.3000	0.0041	0.0045	1.3200	0.0036	0.0039	0.0045	0.0021

Feed Garrett B included all material in the original shale oil boiling up to 650^{o}F, and was fed to high-severity Runs 405 and 406 at liquid hourly space velocities respectively of 0.42 and 0.93. Feed Garrett C included all material in the original shale oil boiling up to 700^{o}F, and was fed to high-severity Runs 407 and 408 at liquid hourly space velocities of 0.43 and 0.97 respectively.

Finally, the Jet A final fuel blend prepared via hydrotreatment of the original kerosene feed fraction in Run 103 in the normal-severity hydrotreatment segment (labeled Feed Garrett 103) was refed to the unit in high-severity Run 415. Hence Product 415 represents doubly hydrotreated material.

All runs made with Garrett feedstocks were conducted over American Cyanamid HDS-3A nickel-molybdenum catalyst.

4.4.2 Distillation of Whole Garrett Hydrotreated Products

The whole hydrotreated products from Runs 115, 103, 404, 405, 407, and 415 were each distilled in a laboratory distillation system capable of atmospheric/vacuum operation. Distillation data for these four operations are presented respectively in Tables 4-17 through 4-22.

4.4.3 Synthetic JP-4 Fuel Blends from Garrett Experiments

The Garrett whole shale oil sample (see Appendix VII) and the feed fractions distilled therefrom contained only small quantities of components boiling below about 310^{o}F. Consequently only narrow-cut Jet A fuel blends could be prepared from the hydrotreated products from our low- or normal-severity runs.

However, it appeared possible to blend wide-cut JP-4-type fuels from the whole hydrotreated products from the high-severity runs. Because of the limited quantities available, a JP-4 fuel blend was prepared only from the product from high-severity Run 404, although it appeared that similar blends could have been prepared from all of the products from the "400" high-severity operations.

Table 4-23 shows available inspections on the JP-4 fuel blends. The JFTOT result is considered indeterminate because of excessive vaporization of the sample in the test apparatus at the test pressure of 400 psig. However, the fuel's thermal breakpoint is very high.

4.4.4 Synthetic Jet A Fuel Blends From Garrett Experiments

Synthetic narrow-cut Jet A-type fuel blends were prepared from the hydrotreated products from low-severity Run 115, normal-severity Run 103, high-severity Run 404, and the material doubly hydrotreated in Runs 103/415. Inspections on the fuel blends, including the Spun Tube JFTOT Deposit Ratings, are shown on Table 4-24.

TABLE 4 -17

DISTILLATION OF WHOLE GARRETT (OCCIDENTAL)
HYDROTREATED PRODUCT
RUN 115 - LOW SEVERITY

Reflux Ratio	Operating Pressure, MM Hg	Stillpot Temp., °F.	Corrected Vapor Temp., °F	Cut No.	Yield Wt. %	Yield Cum. Wt. %
5:1	760	401	147	Start	--	--
		421	285	1	4.6	4.6
		437	327	2	4.5	9.1
		450	359	3	4.4	13.5
5:1		458	381	4	4.5	18.0
4:1		471	417	5	8.8	26.8
		483	433	6	8.9	35.7
		491	448	7	8.7	44.4
4:1	760	501	455	8	8.7	53.1
3:1	100	380	478	9	8.8	61.9
		387	494	10	9.9	71.8
		399	509	11	9.9	81.7
		405	517	12	5.0	86.7
		416	531	13	4.9	91.6
3:1	100	437	549	14	4.8	96.4
			Bottoms Recovered		2.8	99.2

TABLE 4 - 18

DISTILLATION OF WHOLE GARRETT (OCCIDENTAL)
HYDROTREATED PRODUCT
RUN 103 - NORMAL SEVERITY

Reflux Ratio	Operating Pressure, MM Hg	Stillpot Temp., °F.	Corrected Vapor Temp., °F.	Cut No.	Yield Wt. %	Yield Cum Wt. %
4:1	760	370	140	Start	--	--
4:1	760	400	268	1	5.0	5.0
4:1	760	422	310	2	5.0	10.0
4:1	760	440	342	3	5.3	15.3
4:1	760	450	370	4	5.0	20.3
4:1	760	458	394	5	5.1	25.4
4:1	100	342	398	6	5.0	30.4
3:1	100	350	427	7	10.0	40.4
3:1	100	362	440	8	10.0	50.4
3:1	100	376	460	9	10.0	60.4
3:1	100	386	483	10	10.0	70.4
3:1	100	398	500	11	10.0	80.4
3:1	100	406	510	12	5.0	85.4
3:1	100	414	520	13	5.0	90.4
3:1	100	431	540	14	5.0	95.4
			Bottoms Recovered		4.3	99.7

TABLE 4 - 19

DISTILLATION CF WHOLE GARRETT (OCCIDENTAL)
HYDROTREATED PRODUCT
RUN 404 - HIGH SEVERITY

Reflux Ratio	Operating Pressure, MM Hg	Stillpot Temp., °F	Corrected Vapor Temp., °F	Cut No.	Yield Wt. %	Yield Cum. Wt. %
3:1	760	387	167	Start	--	--
3:1	760	390	212	1	0.7	0.7
3:1	760	393	248	2	0.7	1.4
3:1	760	403	275	3	2.5	3.9
3:1	760	416	302	4	3.2	7.1
3:1	760	423	320	5	2.6	9.7
3:1	760	434	347	6	4.2	13.9
3:1	760	448	374	7	7.3	21.2
2:1	10	243	401	8	7.9	29.1
2:1	10	267	428	9	14.6	43.7
2:1	10	283	455	10	14.2	57.9
2:1	100	390	482	11	14.2	72.1
2:1	100	412	509	12	11.6	83.7
2:1	100	430	536	13	7.2	90.9
2:1	100	433	545	14	1.4	92.3
			Bottoms Recovered		7.1	99.4

TABLE 4 - 20

DISTILLATION OF WHOLE GARRETT (OCCIDENTAL)
HYDROTREATED PRODUCT
RUN 405 - HIGH SEVERITY

Reflux Ratio	Operating Pressure, MM Hg	Stillpot Temp., °F	Corrected Vapor Temp., °F	Cut No.	Yield Wt. %	Yield Cum. Wt. %
3:1	760	402	175	Start	--	--
3:1	760	412	248	1	1.5	1.5
3:1	760	420	275	2	1.4	2.9
3:1	760	433	302	3	2.7	5.6
3:1	760	443	320	4	2.4	8.0
3:1	760	452	347	5	3.0	11.0
3:1	760	465	374	6	4.9	15.9
3:1	100	350	401	7	8.4	24.3
3:1	100	370	428	8	8.9	33.2
3:1	100	390	455	9	11.7	44.9
3:1	100	409	482	10	10.6	55.5
3:1	100	427	509	11	10.7	66.2
3:1	100	442	536	12	7.4	73.6
3:1	100	460	563	13	8.3	81.9
3:1	100	485	590	14	7.6	89.5
3:1	100	510	617	15	4.8	94.3
3:1	100	600	640	16	2.3	96.6
			Bottoms Recovered		1.5	98.1

TABLE 4 - 21

DISTILLATION OF WHOLE GARRETT (OCCIDENTAL)
HYDROTREATED PRODUCT
RUN 407 - HIGH SEVERITY

Reflux Ratio	Operating Pressure, MM Hg	Stillpot Temp., °F	Corrected Vapor Temp., °F	Cut No.	Yield Wt. %	Yield Cum. Wt. %
2.5:1	760	420	175	Start	--	--
2.5:1	760	428	248	1	1.1	1.1
2.5:1	760	435	275	2	1.2	2.3
2.5:1	760	448	302	3	2.2	4.5
2.5:1	760	458	320	4	1.7	6.2
3:1	760	472	347	5	3.8	10.0
2:1	100	345	374	6	1.7	11.7
2:1	100	357	401	7	4.8	16.5
2:1	100	395	455	8	17.2	33.7
2:1	100	428	500	9	17.0	50.7
2:1	100	443	515	10	6.4	57.1
2:1	100	446	536	11	3.6	60.7
2:1	100	464	563	12	9.3	70.0
2:1	100	485	590	13	10.7	80.7
2:1	100	507	617	14	7.8	88.5
2:1	100	525	640	15	4.3	92.8
2:1	100	585	675	16	4.3	97.1
			Bottoms Recovered		2.0	99.1

TABLE 4 - 22

DISTILLATION OF WHOLE GARRETT (OCCIDENTAL) HYDROTREATED PRODUCT RUN 415 - HIGH SEVERITY

Reflux Ratio	Operating Pressure, MM Hg	Stillpot Temp., °F	Corrected Vapor Temp., °F	Cut No.	Yield Wt. %	Yield Cum. Wt. %
2:1	760	412	192	Start	--	--
2:1	760	422	302	1	2.8	2.8
2:1	100	315	358	2	6.8	9.6
2:1	100	317	374	3	1.2	10.8
2:1	100	324	401	4	6.3	17.1
2:1	100	343	428	5	31.8	48.9
2:1	100	360	455	6	12.2	61.1
3:1	100	381	482	7	16.9	78.0
3:1	100	394	507	8	13.3	91.3
3:1	100	407	518	9	4.5	95.8
3:1	100	--	530	10	2.1	97.9
			Bottoms Recovered		1.0	98.9

TABLE 4 - 23

SYNTHETIC JP-4 (WIDE-CUT) AVIATION TURBINE FUEL BLEND FROM GARRETT (OCCIDENTAL) SHALE OIL

RUN NO.	404
Total Pressure, PSIG	2200
LHSV	0.48
ASTM Distillation	
IBP	246
5 Percent	275
10	296
20	332
30	383
40	434
50	453
60	463
70	470
80	476
90	486
95	494
FBP	500
Density, GMS/CC @ $60^{o}F$	0.7956
Mass Spectroscopy	
Paraffins	49.2
Monocycloparaffins	33.8
Dicycloparaffins	9.3
Tricycloparaffins	1.7
PARAFFINS, Total	94.0
Alkylbenzenes	5.1
Indans	0.7
Indenes	0.0
Naphthalenes	0.0
AROMATICS, Total	5.8
Sulfur, Total Wt. Percent	0.0056
Nitrogen, Total Wt. Percent	0.0027
JFTOT, Spun Tube Deposit Rating, ^{o}F	>500

TABLE 4 - 24

SYNTHETIC JET A (NARROW-CUT) AVIATION TURBINE FUEL BLENDS FROM GARRETT (OCCIDENTAL) SHALE OIL

RUN NO.	115	103	404	415
Total Pressure, PSIG	800	1500	2200	2200
LHSV	0.91	0.99	0.48	0.56
ASTM Distillation				
IBP	321	345	358	366
5 Percent	359	369	374	384
10	377	383	380	390
20	400	399	389	400
30	420	415	398	410
40	435	429	406	420
50	448	439	414	428
60	458	448	422	437
70	471	459	434	446
80	483	469	446	456
90	499	484	466	469
95	509	493	482	479
FBP	517	502	495	488
Density, GMS/CC @ 60°F	0.8134	0.8051	0.8013	0.7978
Mass Spectroscopy				
Paraffins	46.5	47.3	43.3	49.7
Monocycloparaffins	22.9	30.4	37.9	36.1
Dicycloparaffins	7.0	8.6	12.1	11.6
Tricycloparaffins	1.4	1.2	1.9	1.4
PARAFFINS, Total	77.8	87.5	95.2	98.8
Alkylbenzenes	11.7	7.6	3.4	0.6
Indans	9.5	4.5	1.0	0.3
Indenes	0.2	0.0	0.0	0.0
Naphthalenes	0.5	0.0	0.0	0.0
AROMATICS, Total	21.9	12.1	4.4	0.9
Sulfur, Total Wt. Percent	0.0019	0.0004	0.0036	0.0009
Nitrogen, Total Wt. Percent	0.0052	0.0030	0.0026	0.0015
JFTOT, Spun Tube Deposit Rating, °F	445	585	> 615	> 625

4.4.5 Garrett Whole Product and Jet A Fuel Blend Specifications

In Table 4-25 are presented specification inspections for the feed fraction, whole hydrotreated products, and final narrow-cut Jet A fuel blends prepared from the normal- and low-severity Garrett (Occidental) hydrogenation experiments.

4.5 Synthoil Coal Liquid Hydrotreated Product Characterization

In this section are presented data for the results of the characterization of products derived from the hydrogenation experiments performed with feedstocks distilled from Synthoil coal liquid.

4.5.1 Synthoil Whole Hydrotreated Products

Feedstocks distilled from Synthoil coal liquid were fed to five hydrogenation experiments. These experiments are summarized on Table 4-26 in order of increasing severity.

The kerosene feed fraction distilled from the original whole coal oil sample was fed to low-severity Run 203, and to normal-severity Runs 107, 202, and 105. Note that, in the case of the Synthoil experiments, runs were conducted over cobalt-molybdenum, as well as nickel-molybdenum catalysts.

The feed to Synthoil high-severity Run 416 was the final synthetic Jet A fuel blended from the hydrotreated product from normal-severity Run 107 (labeled Feed 107). Hence, Product 416 represents twice-hydrotreated material.

4.5.2 Distillation of Synthoil Whole Hydrotreated Products

The whole hydrotreated products from Synthoil Runs 203, 107, 202, 105, and 416 were each distilled in a laboratory distillation system capable of atmospheric/vacuum operation. Distillation data for these five distillations are presented respectively in Tables 4-27 through 4-31.

4.5.3 Synthetic Jet A Fuel Blends from Synthoil Experiments

The original Synthoil coal liquid sample contained only a very small quantity of material boiling below about 400°F (see Appendix VIII). Consequently, only narrow-cut Jet A-type fuels could be blended in reasonable yield from the products collected from our Synthoil hydrotreatment experiments.

TABLE 4-25

JET A FROM GARRETT (OCCIDENTAL) SHALE OIL - INSPECTIONS

	SPEC.	ASTM STANDARD	FEED	RUN 103 (1500) TOTAL PRODUCT	RUN 103 (1500) BLENDED FUEL	RUN 115 (800) TOTAL PRODUCT	RUN 115 (800) BLENDED FUEL
AROMATICS, FIA (VOL. %)	MAX. 20	D 1319	--	11.7	10.5	--	20.1
OLEFINS, FIA (VOL. %)		D 1319	--	0.9	0.4	--	1.2
AROMATICS, M.S. (WT. %)			38.9	12.1	12.1	21.5	
BROMINE NO. (CG BR/GM)			23.1	0.24	0.42	0.29	0.38
ANILINE PT. (°F)		D 611	107.5	156.5	157.3	--	145.3
DISTILLATION (°F) INIT.	REPORT	D 86	311.	253.	345.	305.	321.
10%	MAX. 400	D 86	404.	346.	383.	470.	377.
20%			434.	382.	399.	402.	400.
50%	MAX. 450	D 86	469.	442.	439.	452.	448.
90%			510.	497.	484.	503.	499.
FINAL	MAX. 550	D 86	527.	528.	502.	535.	517.
RESIDUE (%)	MAX. 1.5	D 86	SOLID	1.8	1.5	2.0	1.5
LOSS (%)	MAX. 1.5	D 86	--	0.2	0.5	--	0.5
ELEMENTAL ANALYSIS							
CARBON (WT. %)			84.42	85.52	85.07	--	86.34
HYDROGEN (WT. %)			11.84	13.90	13.58	--	13.41
NITROGEN (WT. %)			1.07	0.0074	0.0030	0.0042	0.0052
SULFUR (WT. %)	MAX. 0.3	D 1266	0.63	0.0051	0.0004	0.0049	0.0019
FLASH POINT	MIN. 105	D 93	144.	170.	140.	--	128.
FREEZE POINT	MAX. -36	D 2386	TOO DARK	-23.8	-29.2	-22.0	-22.8
GRAVITY 60°F (°API)	39-51	D 287	33.7	45.1	44.2	42.5	42.5
SPEC. GRAVITY (60/60°F)	0.775-0.830	D 287	0.8565	0.8010	0.8051	0.8133	0.8134
SMOKE POINT (MM)	MIN. 25	D 1322	--	27.0	26.9	--	20.2
VISCOSITY, -30°F (CS)	MAX. 15	D 445	--	CRYSTAL	11.6	CRYSTAL	CRYSTAL

TABLE 4 - 26

SYNTHOIL HYDROTREATMENT EXPERIMENTS

Run No.	Kerosene Feed Fraction	Product 203	Product 107	Product 202	Product 105	FEED 107	Product 416
Total Pressure, PSIG	--	800	1500	1500	1500	--	2200
LHSV	--	0.88	0.95	0.69	0.81	--	0.54
Catalyst	--	Co-Mo	Ni-Mo	Co-Mo	Ni-Mo	--	Ni-Mo
ASTM Distillation							
IBP	~222	269	245	268	250	322	318
5 Percent	404	320	290	319	301	349	349
10	416	358	328	349	330	363	367
20	428	399	377	385	376	387	387
30	443	424	406	407	405	406	402
40	458	442	427	422	424	422	417
50	468	456	442	438	438	434	429
60	478	471	457	452	452	447	439
70	490	485	472	467	468	460	453
80	500	498	489	482	484	473	468
90	514	515	508	500	505	486	483
95	525	529	521	516	520	496	493
FBP	528	546	543	537	542	505	512
Density, GMS/CC @ 60 °F	0.9262	0.8870	0.8667	0.8556	0.8532	0.8670	0.8327
Mass Spectroscopy							
Paraffins	0.5	1.4	3.4	10.7	8.2	3.0	15.9
Monocycloparaffins	38.8	31.2	38.4	41.5	42.3	46.4	54.5
Dicycloparaffins	8.5	12.8	18.2	15.6	19.6	16.7	22.7
Tricycloparaffins	0.0	4.5	8.0	5.7	5.5	4.3	4.9
PARAFFINS, Total	47.8	49.9	68.0	73.5	75.6	70.4	98.0
Alkylbenzenes	21.2	17.3	11.6	12.7	9.4	12.2	1.1
Indans	21.4	25.0	16.4	12.6	10.4	15.5	0.3
Indenes	7.7	2.9	3.4	0.9	4.2	1.5	0.0
Naphthalenes	1.6	5.0	0.2	0.0	0.0	0.0	0.2
AROMATICS, Total	51.9	50.2	31.6	26.2	24.0	29.2	1.6
Sulfur, Total Wt. Percent	0.1000	0.0012	0.0022	0.0020	0.0031	0.0005	<.0001
Nitrogen, Total Wt. Percent	0.3000	0.0062	0.0061	0.0050	0.0053	0.0057	<.0001

TABLE 4- 27

DISTILLATION OF WHOLE SYNTHOIL HYDROTREATED PRODUCT RUN 203 - LOW SEVERITY

Reflux Ratio	Operating Pressure, MM Hg	Stillpot Temp., °F	Corrected Vapor Temp., °F	Cut No.	Yield Wt. %	Yield Cum. Wt. %
4:1	760	387	149	Start	-	-
4:1	760	418	274	1	5.0	5.0
4:1	760	439	331	2	4.9	9.9
4:1	760	452	365	3	5.0	14.9
4:1	760	463	382	4	5.0	19.9
3:1	100	347	412	5	9.9	29.8
3:1	100	363	439	6	9.8	39.6
3:1	100	377	458	7	10.1	49.7
3:1	100	385	478	8	9.8	59.5
3:1	100	397	495	9	10.2	69.7
3:1	100	408	512	10	9.9	79.6
3:1	100	417	520	11	5.0	84.6
3:1	100	423	531	12	5.0	89.6
3:1	100	435	543	13	5.0	94.6
			Bottoms Recovered		4.9	99.5

TABLE 4- 28

DISTILLATION OF WHOLE SYNTHOIL
HYDROTREATED PRODUCT
RUN 107 - NORMAL SEVERITY

Reflux Ratio	Operating Pressure, MM Hg	Stillpot Temp., °F	Corrected Vapor Temp., °F	Cut No.	Yield Wt. %	Yield Cum. Wt. %
4:1	760	368	160	Start	-	-
		401	251	1	5.2	5.2
		422	308	2	4.9	10.1
		437	344	3	4.9	15.0
		448	366	4	5.0	20.0
		466	397	5	10.0	30.0
		483	426	6	10.0	40.0
4:1	760	499	446	7	10.1	50.1
3:1	100	375	463	8	10.0	60.1
		386	482	9	10.0	70.1
		400	501	10	9.9	80.0
		407	511	11	5.0	85.0
		418	523	12	5.0	90.0
3:1	100	435	539	13	5.1	95.1
			Bottoms Recovered		4.4	99.5

TABLE 4- 29

DISTILLATION OF WHOLE SYNTHOIL
HYDROTREATED PRODUCT
RUN 202 - NORMAL SEVERITY

Reflux Ratio	Operating Pressure, MM Hg	Stillpot Temp., °F	Corrected Vapor Temp., °F	Cut No.	Yield Wt. %	Yield Cum. Wt. %
3:1	760	383	170	Start	-	-
3:1	760	407	269	1	4.8	4.8
3:1	760	423	322	2	5.0	9.8
3:1	760	433	351	3	4.9	14.7
3:1	760	443	369	4	5.1	19.8
3:1	760	460	393	5	9.8	29.6
3:1	760	473	417	6	10.0	39.6
2.5:1	100	357	438	7	10.0	49.6
2.5:1	100	368	458	8	10.0	59.6
2.5:1	100	378	473	9	10.0	69.6
2.5:1	100	390	490	10	9.9	79.5
2.5:1	100	397	506	11	5.1	84.6
2.5:1	100	405	517	12	5.0	89.6
2.5:1	100	420	533	13	5.1	94.7
			Bottoms Recovered		5.2	99.9

TABLE 4-30

DISTILLATION OF WHOLE SYNTHOIL
HYDROTREATED PRODUCT
RUN 105 - NORMAL SEVERITY

Reflux Ratio	Operating Pressure, MM Hg	Stillpot Temp., °F.	Corrected Vapor Temp., °F.	Cut No.	Yield Wt. %	Yield Cum. Wt. %
5:1	760	--	--	Start	--	--
		400	244	1	5.0	5.0
		420	303	2	5.1	10.1
		434	341	3	4.9	15.0
		444	364	4	5.0	20.0
		460	393	5	10.0	30.0
		476	417	6	9.9	39.9
5:1	760	492	441	7	10.1	50.0
3:1	100	369	456	8	9.9	59.9
		380	471	9	10.0	69.9
		396	494	10	10.0	79.9
		402	502	11	5.0	84.9
		417	518	12	5.0	89.9
3:1	100	434	535	13	5.1	95.0
		Bottoms Recovered			4.6	99.6

TABLE 4-31

DISTILLATION OF WHOLE SYNTHOIL HYDROTREATED PRODUCT RUN 416 - HIGH SEVERITY

Reflux Ratio	Operating Pressure, MM Hg	Stillpot Temp., °F	Corrected Vapor Temp., °F	Cut No.	Yield Wt. %	Yield Cum. Wt. %
3:1	760	398	208	Start	-	-
3:1	760	413	302	1	4.2	4.2
3:1	760	427	347	2	7.3	11.5
3:1	100	315	374	3	10.7	22.2
3:1	100	328	401	4	11.6	33.8
3:1	100	346	428	5	13.9	47.7
3:1	100	359	455	6	15.0	62.7
3:1	100	377	482	7	16.2	78.9
3:1	100	398	509	8	13.2	92.1
3:1	100	392	530	9	4.1	96.2
				Bottoms Recovered	1.5	97.7

Available inspections for the Jet A fuel blends prepared from each of the Synthoil hydrotreatment experiments, including the Spun Tube JFTOT Deposit Ratings, are shown on Table 4-32.

4.5.4 Synthoil Whole Product and Fuel Blend Specifications

In Table 4-33 are presented specification inspections for the feed fraction, whole hydrotreated products, and final narrow-cut Jet A fuel blends prepared from the normal- and low-severity Synthoil hydrogenation experiments. As indicated above, there were three normal-severity experiments, in which space velocity and catalyst type were varied (Runs 105, 107, and 202), and one low-severity experiment (Run 203), conducted over cobalt-molybdenum catalyst.

4.6 H-Coal Coal Liquid Hydrotreated Product Characterization

In this section are presented data for the results of the characterization of products derived from the hydrogenation experiments performed with H-Coal coal liquid.

4.6.1 H-Coal Whole Hydrotreated Product

H-Coal coal oil was fed to four hydrogenation experiments. These experiments are summarized on Table 4-34. It is noted that H-Coal feed was also used in Run 212, a fifth experiment, for which separate data is not presented here because operation of the unit was considered too erratic to permit description of the conditions under which product was collected (see Section 4.1 above). However, the product collected during Run 212 (labeled "Feed 212") was refed to the unit in high-severity Run 419. Hence "Product 419" represents doubly hydrotreated material.

Note that the H-Coal coal liquid was fed as received directly to our hydrotreatment unit in Runs 304, 209, and 417. That is, this material was presumably already a distillate product with boiling range similar to that of the kerosene feed fractions distilled from our other whole syncrude samples (see Section 3.3.7), and did not require further distillation. As a class, however, the H-Coal experiments were the most troublesome with respect to reactor pressure drop problems, such that conditions under which the products were collected deviated furthest from the ideal steady-state desired, and the inspections reported for particular conditions are thus likely to be least reliable.

Interestingly, the reactor pressure drop problem was incurred with both nickel-molybdenum and cobalt-molybdenum catalysts, and manifested itself identically at all severities. Removal, from the reactor bundle, of two empty reactor tubes employed as a preheat section ahead of the tubes packed with catalyst (see Section 4.1 above) likewise had no effect on the problem.

TABLE 4-32

SYNTHETIC JET A FUEL BLENDS FROM SYNTHOIL HYDROTREATMENT EXPERIMENTS

Run No.	203	107	202	105	416
Total Pressure, PSIG	800	1500	1500	1500	2200
LHSV	0.88	0.95	0.69	0.81	0.54
Catalyst	Co-Mo	Ni-Mo	Co-Mo	Ni-Mo	Ni-Mo
ASTM Distillation					
IBP	340	322	337	331	254
5 Percent	367	349	363	360	330
10	377	363	376	371	357
20	405	387	392	390	387
30	421	406	406	406	399
40	436	422	420	420	413
50	448	434	435	432	422
60	459	447	447	446	433
70	476	460	461	458	444
80	481	473	473	470	457
90	502	486	490	486	472
95	515	496	503	502	482
FBP	524	505	514	509	489
Density, GMS/CC @ 60 °F	0.8882	0.8670	0.8568	0.8550	0.8289
Mass Spectroscopy					
Paraffins	1.0	3.0	10.7	7.9	16.3
Monocycloparaffins	32.8	46.4	41.7	49.0	55.6
Dicycloparaffins	11.5	16.7	15.5	17.9	21.9
Tricycloparaffins	3.8	4.3	5.1	4.0	4.2
PARAFFINS, Total	49.1	70.4	73.0	78.8	98.0
Alkylbenzenes	17.6	12.2	12.7	9.6	1.2
Indans	27.0	15.5	13.3	10.2	0.4
Indenes	2.6	1.5	0.7	1.0	0.0
Naphthalenes	3.2	0.0	0.0	0.0	0.1
AROMATICS, Total	50.4	29.2	26.7	20.8	1.7
Sulfur, Total Wt. Percent	0.0005	0.0005	0.0029	0.0022	0.0004
Nitrogen, Total Wt. Percent	0.0067	0.0057	0.0016	0.0030	0.0029
JFTOT, Spun Tube Deposit Rating, °F	{418}	520	500	540	>560

TABLE 4-33

JET A FROM SYNTHOIL COAL

	Spec.	ASTM Standard	Feed	Run 105 (1500 Ni-Mo) Total Product	Run 105 (1500 Ni-Mo) Blended Fuel	Run 202 (1500 Co-Mo) Total Product	Run 202 (1500 Co-Mo) Blended Fuel
Aromatics, FIA (vol. %)	Max. 20	D1319	Too Dark	20.2	20.2	25.0	24.7
Olefins, FIA (vol. %)		D1319	Too Dark	1.1	1.0	1.0	1.4
Aromatics, M.S. (wt. %)			51.9	24.0	20.8	26.2	26.7
Bromine No. (cg Br/gm)				0.36	0.38	0.36	0.27
Aniline Pt. (°F)		D611	~ 40.	112.9	115.2	108.6	109.2
Distillation (°F) Init.	Report	D86	222.	250.	331.	268.	337.
10%	Max. 400	D86	416.	330.	371.	349.	376.
20%			428.	376.	390.	385.	392.
50%	Max. 450	D86	468.	438.	432.	438.	435.
90%			514.	505.	486.	500.	490.
Final	Max. 550	D86	528.	542.	509.	537.	514.
Residue (%)	Max. 1.5	D86	1.0	1.5	1.6	1.5	1.5
Loss (%)	Max. 1.5	D86	0.5	0.5	0.4	0.0	0.5
Elemental Analysis							
Carbon (wt. %)			86.87	87.00	86.42	86.61	87.41
Hydrogen (wt. %)			11.21	12.88	12.17	12.27	12.33
Nitrogen (wt. %)			0.3000	0.0053	0.0030	0.0050	0.0016
Sulfur (wt. %)	Max. 0.3	D1266	0.1000	0.0031	0.0022	0.0023	0.0029
Flash Point	Min. 105	D93	174	< 75.	134.	98.	136.
Freeze Point	Max. -36	D2386	Too Dark	- 64.3	- 70.6	- 66.1	- 67.0
Gravity, 60°F (°API)	39-51	D287	21.3	34.3	34.0	33.9	33.7
Spec. Gravity (60/60°F)	0.775-0.830	D287	0.9262	0.8532	0.8550	0.8556	0.8568
Smoke Point (mm)	Min. 25	D1322	---	15.7	17.4	15.4	---
Viscosity, -30°F (cs)	Max. 15	D445	50. (Ext.)	11.4	14.1	11.7	12.1

TABLE 4-33 (Cont'd.)

JET A FROM SYNTHOIL COAL

	Spec.	ASTM Standard	Feed	Run 107 (1500 Ni-Mo) Total Product	Run 107 (1500 Ni-Mo) Blended Fuel	Run 203 (800 Co-Mo) Total Product	Run 203 (800 Co-Mo) Blended Fuel
Aromatics, FIA (vol. %)	Max. 20	D1319	Too Dark	27.2	27.8	49.1	48.6
Olefins, FIA (vol. %)		D1319	Too Dark	1.3	1.8	1.0	1.2
Aromatics, M.S. (wt. %)			51.9	31.6	29.2	50.2	50.4
Bromine No. (cg Br/gm)				0.43	0.51	0.59	0.54
Aniline Pt. (°F)		D611	~ 40.	97.9	99.1	66.2	67.5
Distillation (°F) Init.	Report	D86	222.	245.	322.	269.	340.
10%	Max. 400	D86	416.	328.	363.	358.	377.
20%			428.	377.	387.	399.	405.
50%	Max. 450	D86	468.	442.	434.	456.	448.
90%			514.	508.	486.	515.	502.
Final	Max. 550	D86	528.	543.	505.	546.	524.
Residue (%)	Max. 1.5	D86	1.0	1.7	1.5	1.5	2.2
Loss (%)	Max. 1.5	D86	0.5	0.3	0.5	0.0	0.3
Elemental Analysis							
Carbon (wt. %)			86.87	87.96	87.24	87.62	88.76
Hydrogen (wt. %)			11.21	12.07	12.03	11.01	11.08
Nitrogen (wt. %)			0.3000	0.0061	0.0057	0.0062	0.0067
Sulfur (wt. %)	Max. 0.3	D1266	0.1000	0.0022	0.0005	0.0012	0.0005
Flash Point	Min. 105	D93	174	72.	126.	102.	140.
Freeze Point	Max. -36	D2386	Too Dark	-70.6	-77.8	-59.8	-67.0
Gravity, 60°F (°API)	39-51	D287	21.3	31.8	31.7	28.0	27.8
Spec. Gravity (60/60°F)	0.775-0.830	D287	0.9262	0.8667	0.8670	0.8870	0.8882
Smoke Point (mm)	Min. 25	D1322	---	12.3	13.9	10.4	9.1
Viscosity, -30°F (cs)	Max. 15	D445	50. (Ext.)	12.8	14.1	14.4	14.4

TABLE 4-34

H-COAL HYDROTREATMENT EXPERIMENTS

	Feed Fraction (as Rcvd.)	Product 304	Product 209	Product 417	Feed 212	Product 419
Total Pressure, PSIG	--	800	1500	2200	-	2200
LHSV	-	0.99	0.95	0.54	-	0.49
Catalyst	-	Co-Mo	Co-Mo	Ni-Mo	-	Ni-Mo
ASTM Distillation						
IBP	177	212	193	237	260	282
5 Percent	212	244	231	272	296	317
10	234	266	252	292	312	335
20	268	292	284	324	337	356
30	297	321	319	352	358	372
40	328	345	346	374	376	385
50	356	366	365	392	391	396
60	376	386	385	408	404	407
70	397	406	404	427	419	419
80	422	427	424	449	436	434
90	464	463	454	476	462	454
95	510	495	483	496	486	471
FBP	544	534	506	523	518	496
Density, GMS/CC @ $60^{o}F$	0.8567	0.8434	0.8252	0.8317	0.8337	0.8070
Mass Spectroscopy						
Paraffins	1.4	5.0	10.0	4.6	17.3	28.4
Monocycloparaffins	43.4	48.9	56.4	70.5	44.2	53.9
Dicycloparaffins	8.3	8.9	11.3	18.4	10.2	12.9
Tricycloparaffins	1.6	1.1	1.9	3.2	2.0	2.9
PARAFFINS, Total	54.7	63.9	79.6	96.7	73.7	98.1
Alkylbenzenes	24.2	20.6	14.4	2.1	14.6	1.0
Indans	17.2	14.7	5.8	0.6	10.5	0.3
Indenes	0.2	0.2	0.0	0.0	0.4	0.0
Naphthalenes	3.2	0.2	0.0	0.2	0.4	0.2
AROMATICS, Total	44.8	35.7	20.2	2.9	25.9	1.5
Sulfur, Total Wt. Percent	0.5500	0.0027	-	0.0026	0.0015	<0.0001
Nitrogen, Total Wt. Percent	0.1200	0.0026	0.0019	<0.0001	<0.0001	<0.0001

4.6.2 Distillation of H-Coal
Whole Hydrotreated Products

The whole hydrotreated products from Runs 304, 209, and 419 were distilled in a laboratory system capable of atmospheric/vacuum operation. Distiliation data for these three operations are presented, respectively, in Tables 4-35 through 4-37.

4.6.3 Synthetic JP-4 Fuel Blends
From H-Coal Experiments

It was generally possible, in the case of the H-Coal experiments, to blend both narrow-cut Jet A fuels and wide-cut JP-4 fuels from the hydrotreated products. Table 4-38 shows data for the wide-cut JP-4 type fuels blended from the products from low-severity Run 304 and from normal-severity Run 209. A JP-4 fuel was not blended from the high-severity Run 419 product only because of limitation of the available material.

4.6.4 Synthetic Jet A Fuel
Blends From H-Coal Experiments

Table 4-39 shows data for the narrow-cut Jet A-type fuels blended from the hydrotreated products from low-severity Run 304, normal-severity Run 209, and high-severity Run 419.

4.6.5 H-Coal Whole Product and
JP-4 Fuel Blend Specifications

Specification inspections for the feed, whole hydrotreated products, and final JP-4 fuel blends prepared from the normal- and low-severity H-Coal hydrogenation experiments are presented in Table 4-40.

4.6.6 H-Coal Whole Product and
Jet A Fuel Blend Specifications

In Table 4-41 are presented specification inspections for the feed, whole hydrotreated products, and final Jet A narrow-cut fuel blends prepared from the normal- and low-severity H-Coal hydrogenation experiments. Again, there was insufficient product from the high-severity Run 419 with which to prepare enough fuel to permit similar inspections.

TABLE 4-35

DISTILLATION OF WHOLE H-COAL
HYDROTREATED PRODUCT RUN 304 - LOW SEVERITY

Reflux Ratio	Operating Pressure, MM Hg	Stillpot Temp., °F	Corrected Vapor Temp., °F	Cut No.	Yield Wt. %	Yield Cum. Wt. %
4:1	760	300	133	Start	-	-
4:1	760	316	203	1	4.4	4.4
4:1	760	333	217	2	4.5	8.9
4:1	760	352	249	3	4.5	13.4
4:1	760	365	271	4	4.7	18.1
4:1	760	387	311	5	9.5	27.6
4:1	760	405	343	6	9.7	37.3
4:1	760	424	367	7	9.9	47.2
4:1	760	439	387	8	10.1	57.3
3:1	100	328	411	9	10.4	67.7
3:1	100	349	437	10	10.4	78.1
3:1	100	363	455	11	5.3	83.4
3:1	100	383	475	12	5.3	88.7
3:1	100	417	505	13	5.2	93.9
				Bottoms	4.6	98.5

TABLE 4-36

DISTILLATION OF WHOLE H-COAL HYDROTREATED PRODUCT RUN 209 - NORMAL SEVERITY

Reflux Ratio	Operating Pressure, MM Hg	Stillpot Temp., ^{o}F	Corrected Vapor Temp., ^{o}F	Cut No.	Yield Wt. %	Yield Cum. Wt. %
3:1	760	290	103	Start	-	-
3:1	760	309	198	1	5.2	5.2
3:1	760	326	213	2	4.1	9.3
3:1	760	345	241	3	4.7	14.0
3:1	760	363	270	4	4.7	18.7
2.5:1	100	267	320	5	10.0	28.7
2.5:1	100	277	345	6	10.0	38.7
2.5:1	100	292	365	7	10.0	48.7
2.5:1	100	309	385	8	10.3	59.0
2.5:1	100	329	413	9	10.3	69.3
2.5:1	100	350	439	10	10.2	79.5
2.5:1	100	361	454	11	5.2	84.7
2.5:1	100	379	475	12	5.3	90.0
2.5:1	100	407	505	13	5.2	95.2
				Bottoms	4.3	99.5

TABLE 4-37

DISTILLATION OF WHOLE H-COAL
HYDROTREATED PRODUCT RUN 419 - HIGH SEVERITY

Reflux Ratio	Operating Pressure, MM Hg	Stillpot Temp., °F	Corrected Vapor Temp., °F	Cut No.	Yield Wt. %	Yield Cum. Wt. %
3:1	760	370	188	Start	-	-
3:1	760	382	248	1	3.2	3.2
3:1	760	392	280	2	3.5	6.7
3:1	760	399	307	3	3.6	10.3
3:1	760	418	347	4	11.5	21.8
3:1	760	437	374	5	16.5	38.3
3:1	100	323	401	6	13.1	51.4
3:1	100	340	428	7	14.9	66.3
3:1	100	360	455	8	14.4	80.7
3:1	100	384	482	9	10.0	90.7
3:1	100	400	509	10	5.5	96.2
				Bottoms	1.5	97.7

TABLE 4-38

SYNTHETIC JP-4 BLENDS FROM
H-COAL HYDROTREATMENT EXPERIMENTS

Run No.	304	209
Total Pressure, PSIG	800	1500
LHSV	0.99	0.95
Catalyst	Co-Mo	Co-Mo
ASTM Distillation		
IBP	205	190
5 Percent	229	217
10	239	226
20	256	245
30	268	263
40	282	284
50	302	306
60	319	328
70	335	348
80	351	363
90	370	380
95	390	398
FBP	422	427
Density, GMS/CC @ 60°F	0.8134	0.8062
Mass Spectroscopy		
Paraffins	4.9	7.3
Monocycloparaffins	60.5	66.5
Dicycloparaffins	4.0	6.6
Tricycloparaffins	0.0	0.0
PARAFFINS, Total	69.4	80.4
Alkylbenzenes	25.0	17.0
Indans	5.4	2.4
Indenes	0.0	0.0
Naphthalenes	0.0	0.0
AROMATICS, Total	30.4	19.4
Sulfur, Total Wt. Percent	0.0003	0.0011
Nitrogen, Total Wt. Percent	0.0026	0.0024
JFTOT, Spun Tube Deposit Rating, °F	475	535

TABLE 4-39

SYNTHETIC JET A BLENDS
FROM H-COAL EXPERIMENTS

Run No.	304	209	419
Total Pressure, PSIG	800	1500	2200
LHSV	0.99	0.95	0.49
Catalyst	Co-Mo	Co-Mo	Ni-Mo
ASTM Distillation			
IBP	347	340	354
5 Percent	364	360	369
10	372	369	373
20	384	381	380
30	394	392	388
40	403	402	396
50	410	410	403
60	419	420	411
70	427	429	421
80	439	441	434
90	456	454	450
95	469	467	463
FBP	480	476	474
Density, GMS/CC @ 60°F	0.8724	0.8464	0.8113
Mass Spectroscopy			
Paraffins	4.6	12.9	30.6
Monocycloparaffins	38.6	46.7	52.7
Dicycloparaffins	12.5	16.2	13.1
Tricycloparaffins	2.1	3.4	2.3
PARAFFINS, Total	57.8	79.2	98.7
Alkylbenzenes	16.7	10.9	0.8
Indans	24.5	9.5	0.1
Indenes	0.4	0.0	0.0
Naphthalenes	0.0	0.0	0.0
AROMATICS, Total	41.6	20.4	0.9
Sulfur, Total Wt. Percent	0.0006	0.0016	<0.0001
Nitrogen, Total Wt. Percent	0.0027	0.0047	0.0026
JFTOT, Spun Tube Deposit Rating, °F	382	505	>515

TABLE 4-40

JP-4 FROM H-COAL LIQUID
INSPECTIONS

	Spec.	ASTM Standard	Feed	Run 209 (1500) Total Product	Run 209 (1500) Blended Fuel	Run 304 (800) Total Product	Run 304 (800) Blended Fuel
Aromatics, FIA (vol. %)	Max. 25.0	D1319	-	17.3	16.5	32.6	23.8
Olefins, FIA (vol. %)	Max. 5.0	D1319	-	1.2	0.9	0.2	0.4
Aromatics, M.S. (wt. %)			44.8	20.2	19.4	35.7	30.4
Bromine No. (cg Br/gm)			10.7	0.20	0.15	0.28	0.19
Aniline Pt. (^{o}F)		D611	48.5	106.5	98.1	77.6	80.6
Distillation (^{o}F) Init.	Report	D86	177.	193.	190.	212.	205.
10%	Report	D86	234.	252.	226.	266.	239.
20%	Max. 290	D86	268.	284.	245.	292.	256.
50%	Max. 370	D86	356.	365.	306.	366.	302.
90%	Max. 470	D86	464.	454.	380.	463.	370.
Final	Report	D86	544.	506.	427.	534.	422.
Residue (%)	Max. 1.5	D86	1.8	1.6	1.2	1.5	1.5
Loss (%)	Max. 1.5	D86	0.7	0.4	0.3	0.5	0.5
Elemental Analysis							
Carbon (wt. %)			86.30	86.14	85.84	85.70	87.18
Hydrogen (wt. %)			11.96	12.62	14.29	12.33	12.61
Nitrogen (wt. %)			0.12	0.0019	0.0024	0.0026	0.0026
Sulfur (wt. %)	Max. 0.40	D1266	0.55	-	0.0011	0.0027	0.0003
Flash Point		D93	<65.	<50.	<40.	56.	<40.
Freeze Point	Max. -72	D2386	Too dark	<-94	<-94.	<-88.	<-94.
Gravity, 60^{o}F (^{o}API)	45-57	D287	33.7	40.0	44.0	36.3	42.5
Spec. Gravity (60/60^{o}F)	.802-.751	D287	0.8567	0.8252	0.8062	0.8434	0.8134
Smoke Point (mm)		D1322	-	20.60	21.56	10.68	17.49
Viscosity, -30^{o}F (cs)		D445	-	4.88	3.07	4.87	2.82

TABLE 4-41

JET A FROM H-COAL LIQUID
INSPECTIONS

	Spec.	ASTM Standard	Feed	Run 209 (1500) Total Product	Run 209 (1500) Blended Fuel	Run 304 (800) Total Product	Run 304 (800) Blended Fuel
Aromatics, FIA (vol. %)	Max. 20	D1319	--	17.3	18.5	32.6	37.4
Olefins, FIA (vol. %)		D1319	--	1.2	0.8	0.2	1.6
Aromatics, M.S. (wt.%)			44.8	20.2	20.4	35.7	41.6
Bromine No. (cg Br/gm)			10.7	0.20	0.18	0.28	0.39
Aniline Pt. (°F)		D611	48.5	106.5	115.8	77.6	76.9
Distillation (°F) Init.	Report	D86	177	193	340	212	347
10%	Max. 400	D86	234	252	369	266	372
20%			268	284	381	292	384
50%	Max. 450	D86	356	365	410	366	410
90%			464	454	454	463	456
Final	Max. 550	D86	544	506	476	534	480
Residue (%)	Max. 1.5	D86	1.8	1.6	1.5	1.5	2.0
Loss (%)	Max. 1.5	D86	0.7	0.4	0.5	0.5	0.0
Elemental Analysis							
Carbon (wt. %)			86.30	86.14	86.73	85.70	87.91
Hydrogen (wt.%)			11.96	12.62	12.66	12.33	11.70
Nitrogen (wt. %)			0.1200	0.0019	0.0047	0.0026	0.0027
Sulfur (wt. %)	Max. 0.3	D1266	0.5500		0.0016	0.0027	0.0006
Flash Point	Min. 105	D93	<65	<50	134	56	138
Freeze Point	Max. -36	D2386	Too Dark	<-94	-47	<-88	<-94
Gravity 60°F (°API)	39-51	D287	33.7	40.0	35.7	36.3	30.7
Spec. Gravity (60/60°F)	0.775-0.830	D287	0.8567	0.8252	0.8464	0.8434	0.8724
Smoke Point (mm)	Min. 25	D1322	--	20.60	17.97	10.68	9.71
Viscosity, -30°F (cs)	Max. 15	D445	--	4.88	9.35	4.87	9.36

4.7 Jet Fuel Thermal Oxidation Tests

The Alcoa, Inc. "Jet Fuel Thermal Oxidation Tester" was employed to assess the tendency of synthetic fuel blends prepared in this program to form deposits within the fuel system of an aircraft turbine. The apparatus and the general procedures involved in this assessment are described in detail in Appendix IV to this report. Results are shown in Appendix X.

In this section the results obtained for the fuel blends tested are discussed. Each test was assigned a "D" number in chronological order as the particular blends became available for testing during the course of the program. Table 4-42 is an index to the JFTOT results by "D" number, the order in which they are presented in this section. Table 4-43 is a cross-index to the JFTOT results by derivative crude oil type and by hydrotreatment severity and hydrogenation unit run number. Detailed data are shown in the appendix.

4.7.1 Spun Tube Deposit Rating

Note that, in general, a single test, which is performed at a particular temperature (or setting of the heater tube control temperature), yields a plot of visual spot tube ratings against tube length. A Spun Tube Rating is also obtained using the Alcor Mark 8A Tube Deposit Rater, wherein the test heater tube is traversed along its length while being spun to determine a single maximum deposit reading for that tube. Spun Tube Ratings obtained at several temperatures are plotted against temperature to determine that temperature at which a rating of 13.0 occurs. This determination is reported as the "breakpoint temperature" for the fuel blend (See Appendix IV). The higher the breakpoint temperature, the more stable the fuel. A breakpoint temperature of 500°F is considered marginally acceptable for a commercial fuel.

Note that at least two tests (at different temperatures) are required to permit determination of the breakpoint temperature (by straight-line extrapolation or interpolation). Errors associated with the determination are a function of many variables; but, in general, the determination becomes highly accurate as repetitive tests bracket the breakpoint.

It has been observed that the slope of the Spun Tube Rating vs. temperature line is relatively uniform for similar or related test fuels. Moreover, the breakpoint temperatures of closely related fuels are likely to fall within a limited range. Because our supply of synthetic feed was limited in this program, so that product quantities were also generally severely limited, it was not always possible to run multiple JFTOT determinations on each fuel blend. In such cases, the JFTOT test was performed at a temperature equal to the breakpoint of a fuel previously tested, and considered most nearly similar to the fuel under test. The breakpoint was determined by extrapolating a straight line through the single point with slope equal to that exhibited by the rating curve of the comparative fuel.

4.7.2 JFTOT Results

In this section are discussed all of the JFTOT data collected for the fuel blends prepared in this program. For each test there is a completed "Alcor Oxidation Test Sheet" (Figures D-1 through D-44), a "Tube Rating Repeatability and Reproducibility Study" (Tables D-1 through D-44),

TABLE 4-42

CHRONOLOGICAL INDEX TO JFTOT RESULTS

Test No.	Test Fuel	Test Temp. (°F)	Estimated Breakpoint (°F)
D-1	Jet A CK 14235	550	<550
D-2	Paraho 11-B, Cut 4	550	--
D-3	Paraho 11-B, Cut 4	570	~570
D-4	Tosco 17-B, Light Blend	570	~580
D-5	Tosco 17-B, Heavy	570	--
D-6	Tosco 17-B, Heavy	600	~685
D-7	Garrett 103 Final Blend	600	585
D-8	Synthoil 105 Final	600	--
D-9	Synthoil 105 Final	550	--
D-10	Synthoil 105 Final	525	540
D-11	Synthoil 107 Final	525	--
D-12	Synthoil 107 Final	510	520
D-13	Tosco 113 Alpha	550	--
D-14	Tosco 113 Alpha	520	534
D-15	Tosco 113 Beta	535	--
D-16	Tosco 113 Beta	505	--
D-17	Tosco 113 Beta	485	482
D-18	Synthoil 203 Final	525	--
D-19	Synthoil 203 Final	470	--
D-20	Synthoil 203 Final	400	418
D-21	Garrett 115 Final	525	--
D-22	Garrett 115 Final	450	445
D-23	Paraho 111, Final	425	400
D-24	Synthoil 202 Final	525	--
D-25	Synthoil 202 Final	425	--
D-26	Synthoil 202 Final	450	--
D-27	Synthoil 202 Final	475	--
D-28	Synthoil 202 Final	500	500
D-29	H-Coal 209 Light Final	525	535
D-30	H-Coal 209 Heavy Final	525	505
D-31	H-Coal 304 Light Final	450	475
D-32	H-Coal 304 Heavy Final	435	--
D-33	H-Coal 304 Heavy Final	385	382
D-34	Garrett 415 Final	600	--
D-35	Garrett 415 Final	625	>625
D-36	Synthoil 416 Final	560	--
D-37	Paraho 414 Final	590	--
D-37A	Paraho 414 Final	515	--
D-38	Tosco 410 Heavy Final	575	>575
D-39	Garrett 404 Heavy Final	565	--
D-40	Garrett 404 Heavy Final	590	--
D-41	Garrett 404 Heavy Final	615	>615
D-42	H-Coal 419 Final Blend	515	--
D-43	Garrett 404 Light Final	500	--
D-44	Tosco 410 Light Final	515	--

TABLE 4-43

INDEX TO JFTOT RESULTS BY CRUDE OIL TYPE AND HYDROTREATMENT SEVERITY

	Low Severity		Normal Severity		High Severity	
	Run No.	JFTOT	Run No.	JFTOT	Run No.	JFTOT
Paraho	111	D-23	11B	D-2, -3	414	D-37, -37A
Tosco	113	*D-13, -14	17B	*D-4	410	D-38
	113	D-15 to -17	17B	D-5, -6	410	*D-44
Garrett	115	D-21, -22	103	D-7	415	D-34, -35
					404	D-39 to -41
					404	D-43
Synthoil	203	D-18 to -20	105	D-8 to -10	416	D-36
			107	D-11, -12		
			202	D-24 to -28		
H-Coal	304	D-31	209	*D-29	419	D-42
	304	D-32, -33	209	D-30		

* Signifies wide-cut (JP-4) type fuel blend. All other samples narrow-cut (Jet A) type fuel blends.

and appropriate plots of Spun Tube Deposit Rating vs. Test Temperature (Figures 4-1 through 4-24). In the brief description of each test given below, the reader is referred to the appropriate figures and tables which are shown in the appendix.

Test D-1 was for a commercial Jet A sample which we have sometimes used as feed to our hydrotreating pilot plant. Indications were that this material's breakpoint is below 550°F.

Tests D-2 and D-3 were performed on synthetic jet fuel prepared from Paraho shale oil, indicating a breakpoint of about 570°F (see Figure 4-1).

A breakpoint in excess of 570°F is indicated (Figure 4-2) for a wide-cut (JP-4) synthetic jet fuel prepared from TOSCO shale oil in Test D-4. Tests D-5 and D-6 indicate a breakpoint in excess of 600°F for a narrow-cut (Jet A) synthetic jet fuel prepared from the same TOSCO shale oil (see Figure 4-3).

Test D-7 was performed on synthetic Jet A produced from Garrett shale oil in Run 103, made at 1500 psig over nickel-molybdenum catalyst. The indication is that the breakpoint for this material is in excess of 600°F, the tube temperature used in Test D-7 (see Figure 4-4).

Tests D-8, D-9, and D-10 were performed on Jet A produced from Synthoil coal liquid in Run 105 at 1500 psig over nickel-molybdenum catalyst. Note that Test D-8 was at 600°F, D-9 at 550°F, and D-10 at 525°F. The Spun Tube Deposit Rating obtained with an Alcor MK 8-A is plotted against temperature in Figure 4-5, indicating an acceptable breakpoint of 537°F for this material.

Similarly, JFTOT Tests D-11, at 525°F, and D-12, at 510°F, were performed on a Jet A blend produced from Synthoil coal liquid in Run 107 at 1500 psig over nickel-molybdenum. The plot of Spun Tube Deposit Rating versus temperature shown in Figure 4-6 indicates a breakpoint of 521°F for this material, which is also probably acceptable.

It appears, from the foregoing, that turbine fuels produced from syncrudes at reactor pressures of 1500 psig were all acceptable from a thermal stability standpoint. Fuels produced from the three shale oils were exceptionally stable, whereas fuels produced from the Synthoil coal liquid may have been only marginally acceptable.

Tests D-13 and D-14 were performed on synthetic JP-4 manufactured from TOSCO shale oil in Run 113, made at 800 psig over nickel-molybdenum catalyst. Test D-13 was performed at 550°F, and Test D-14 at 520°F. The Spun Tube Deposit Rating is plotted against temperature in Figure 4-7, indicating an acceptable breakpoint of 534°F for this material. It was especially interesting to find that a relatively stable fuel could be produced from this shale oil using only low-severity hydrotreatment and distillation.

Tests D-15 at 535°F, D-16 at 505°F, and D-17 at 485°F were all run on a synthetic Jet A blend prepared from the same TOSCO shale oil low-severity Run 113. (It is possible to produce both JP-4 and Jet A blends from hydrotreated TOSCO shale oil). The extrapolated Spun Tube Deposit Rating shown in Figure 4-8, of about 481°F, is not acceptable, indicating that low-severity hydrotreatment does not produce the required transformation of higher-boiling species (compare Run 17B at 1500 psig).

Tests D-18 at 525°F, D-19 at 470°F, and D-20 at 400°F were performed on a synthetic Jet A blend prepared from synthoil coal liquid which was hydrotreated over cobalt-molybdenum catalyst at 800 psig in Run 203 of the low-severity phase of our operations. The Spun Tube Deposit Rating is plotted against temperature in Figure 4-9, indicating an unacceptable breakpoint of about 418°F for this material.

Tests D-21 at 525°F and D-22 at 450°F were run on a synthetic Jet A blend prepared from the low-severity Occidental Run 115 hydrotreated product. Again, the Spun Tube Deposit Rating shown in Figure 4-10, of about 445°F, is not acceptable.

Test D-23 at 425°F run on a synthetic Jet A blend prepared from the low-severity Paraho Run 111 indicated an unacceptable rating for this material. Figure 4-11 indicates that a Spun Tube Deposit Rating, also unacceptable, of about 400°F may be estimated.

Hence our experience indicates that low-severity (800 psi) hydrotreatment does not normally suffice to convert those species affecting thermal stability adversely in the particular shale oil and coal feeds we have been using.

Tests D-24 through D-28 were performed on a synthetic Jet A blend prepared from Synthoil coal liquid which was hydrotreated over cobalt-molybdenum catalyst at 1500 psig in Run 202 of the normal severity phase of our operations. The Spun Tube Deposit Rating is plotted against temperature in Figure 4-12; indicating a marginally acceptable breakpoint of just under 500°F for this material. The sample exhibited well-defined properties, and this result is encouraging.

Test D-29 was performed on a synthetic JP-4 blend prepared from H-Coal coal liquid which was hydrotreated at 1500 psig over cobalt-molybdenum in Run 209 of the normal severity phase of our operations. The Spun Tube Deposit Rating is plotted against temperature in Figure 4-13, indicating an acceptable breakpoint of about 533°F for this material.

Test D-30 was performed on a synthetic Jet A blend prepared from the same H-Coal product produced in Run 209. As indicated in Figure 4-14, the Jet A blend exhibits a marginally acceptable Spun Tube Deposit Rating of about 505°F.

Test D-31 was performed on a synthetic JP-4 blend prepared from H-Coal coal liquid which was hydrotreated at 800 psig over cobalt-molybdenum in Run 304 of the low-severity phase of our operations. The Spun Tube Deposit Rating, shown in Figure 4-15, indicates an unacceptable breakpoint of 475°F for this material.

Similarly, Tests D-32 and D-33 were performed on a synthetic Jet A blend prepared from the same low-severity Run 304. The Spun Tube Deposit Rating, shown in Figure 4-16, indicates an unacceptable breakpoint of 382°F for this material.

Tests D-34 and D-35 were performed on a synthetic Jet A blend prepared from Garrett shale oil which had been hydrotreated at 2200 psig over HDS-3A nickel molybdenum catalyst in Run 415 of the high-severity segment of our operations. Note that the feed to Run 415 was hydrotreated product previously collected from Run 103, a normal-severity hydrotreatment operation. Hence the material undergoing test in JFTOT Runs D-34 and D-35 is the product of two-stage hydrotreatment, indicated to contain less than 1.0 weight percent aromatics. The Spun Tube Deposit Rating is plotted against temperature in Figure 4-17, indicating an acceptable breakpoint for this material in excess of 625°F.

Test D-36 was performed on a synthetic Jet A blend prepared from Synthoil coal liquid which had been hydrotreated at 2200 psig over nickel-molybdenum in Run 416 of the high-severity phase of our operations. Note that the feed to Run 416 had been previously hydrotreated in Run 107, a normal-severity hydrotreatment operation. The material undergoing test in JFTOT Run D-36 is indicated to contain 1.6 weight percent aromatics. Although as is indicated in Figure 4-18, the Spun Tube Deposit Rating is probably acceptable, and in excess of 560°F, the test is considered inconclusive, since the fuel sample was found to vaporize excessively in the test apparatus at this temperature (at 400 psi).

Tests D-37 and D-37A were performed on a synthetic Jet A blend prepared from Paraho shale oil which had been hydrotreated at 2200 psig over nickel-molybdenum catalyst in Run 414 of the high-severity segment of our operations. The feed to Run 414 was also hydrotreated product previously collected from Run 11B, a normal-severity hydrotreatment operation. The material undergoing test in JFTOT Runs D-37 and D-37A is indicated to contain 0.9 weight percent aromatics. Again, as indicated in Figure 4-19, the Spun Tube Deposit Rating is probably acceptable, the breakpoint being in excess of 590°F; however, these tests also are considered inconclusive because of excessive vaporization of the sample in the test apparatus.

Test D-38 was performed on a synthetic Jet A fuel blend prepared from a TOSCO shale oil fraction which had been hydrotreated at 2200 psig over HDS-3A nickel-molybdenum catalyst in Run 410 of the high-severity segment of our operations. The feed to Run 410 was essentially identical with the "kerosene" feed fraction employed in our low- and normal-severity TOSCO experiments. The Jet A blend undergoing test in D-38 was indicated to contain less than 2.0 percent total aromatics by mass spectroscopy. The Spun Tube Deposit Rating is plotted against temperature in Figure 4-20, indicating an acceptable breakpoint for this material in excess of 575°F.

Tests D-39, D-40, and D-41 were all performed on a synthetic Jet A fuel blend prepared from a Garrett (Occidental) shale oil fraction which had been hydrotreated at 2200 psig over nickel-molybdenum in Run 404 of the high-severity segment of our operations. The feed to Run 404 was identical with the feed fraction employed in our low- and normal-severity Garrett hydrotreatment experiments. The Jet A blend undergoing test was indicated to contain 4.4 percent total aromatics by mass spectroscopy. As indicated in Figure 4-21, whereon the Spun Tube Deposit Rating is plotted against temperature, this fuel blend was found to be quite stable, with breakpoint in excess of 615°F.

Test D-42 was performed on a synthetic Jet A fuel blend prepared from H-Coal liquid which had been hydrotreated at 2200 psig over HDS-3A nickel-molybdenum catalyst in Run 419 of the high-severity segment of our operations. The feed to Run 419 was hydrotreated product previously prepared in Run 212 in the low-severity phase of our operations. Hence, the material undergoing test in this case represented doubly hydrotreated fuel and was indicated to contain 1.5 percent aromatics. The single Spun Tube Deposit Rating plotted on Figure 4-22 would suggest the breakpoint for this fuel blend to be in excess of 550°F. The spot ratings shown on Figure D-42 are also eminently acceptable. However, the test is considered inconclusive because of evidence of excessive fuel vaporization in the test apparatus at 400 psig.

Test D-43 was performed on a JP-4 fuel blend prepared from the Garrett (Occidental) shale oil fraction which had been hydrotreated at 2200 psig over nickel-molybdenum catalyst in Run 404 of the high-severity segment of our experimental operations. The feed to Run 404 was identical with the feed fraction employed in our low- and normal-severity Garrett hydrotreatment experiments. The JP-4 blend undergoing test was indicated to contain 5.8 percent total aromatics by mass spectroscopy. The Spun Tube Deposit Rating shown on Figure 4-23 would suggest an acceptable breakpoint in excess of 575°F for this material. As in the previous case, however, this test also is considered inconclusive because of excessive fuel vaporization in the test apparatus.

Test D-44 was performed on a synthetic JP-4 fuel blend prepared from a TOSCO shale oil fraction which had been hydrotreated at 2200 psig over HDS-3A nickel-molybdenum catalyst in Run 410 of the high severity segment of our operations. The feed to Run 410 was essentially identical with the "kerosene" feed fraction employed in our low- and normal-severity TOSCO experiments. The JP-4 fuel blend undergoing test in D-44 was indicated to contain 2.5 percent total aromatics by mass spectroscopy. The Spun Tube Deposit Rating is shown on Figure 4-24, suggesting a breakpoint in excess of 575°F for this material. Again, the test is considered inconclusive because of excessive fuel vaporization within the test apparatus at the test pressure of 400 psig.

In general, we have found that synthetic feedstocks, whether derived from coal or shale, will result in thermally stable fuels, as indicated by the JFTOT procedure, if hydroprocessed at our high-severity conditions. Once-through hydrotreatment at our low-severity conditions will generally result in unacceptable or marginal products. The minimum degree of once-through treatment which will produce an acceptable product is most often indicated to lie between the low- and normal-severity conditions for the shale oils, and above the normal-severity conditions for the coal liquids. Jet A results are summarized in Table 4-44.

Moreover, acceptable JP-4 type fuel could be produced using a lesser degree of hydrotreatment, when it could be produced at all, than was required to permit blending of an acceptable Jet A fuel from a given hydrotreated product. For example, JP-4 blended from the low-severity hydrotreated TOSCO Run 113 product was given an acceptable rating in the JFTOT thermal stability test, whereas the Jet A blended from that same hydrotreated product was found to be unacceptable.

TABLE 4-44

EFFECT OF HYDROPROCESSING SEVERITY ON JFTOT BREAKPOINT TEMPERATURES OF JET A FUELS FROM VARIOUS SYNTHETIC SOURCES

	JFTOT Breakpoint Temperature, °F		
	Low Severity	Normal Severity	High Severity
Paraho	400	570	>590
Tosco	482	658	>575
Garrett	445	585	>625 >615
Synthoil	418	540 520 500	>560
H-Coal	475	505	>550

SECTION V

DISCUSSION

5.1 Program Scope

This program's principal objective was to demonstrate that specification aviation turbine fuels could be produced from synthetic crude oils. It was recognized that the scope of the experimental work would be limited in that direct catalytic hydrotreating of the lower boiling fraction of the synthetic crude oil would be the only processing route investigated, and that even within the limitation many areas such as optimization of process parameters for maximum yields and the effect on catalyst activity of prolonged, continuous exposure to synthetic crude oils could not be investigated. Rather, it was intended that this initial effort could serve as the basis for extended future studies.

In this program, it was desired to make comparisons among certain available synthetic crude oil feedstocks. The program sponsors selected three shale oils and two coal liquids to be used as feedstocks for the experimental phase. It was further desired to investigate the gross effects of hydrotreatment severity at several levels on the quality of the fuels produced. Finally, we intended to generate, in the experimental phase, sufficient operating and analytical information to form a basis for a preliminary economic and engineering appraisal of the effect of the use of synthetic crude oil in a refinery processing both petroleum and synthetic crude to produce a full commercial product slate including jet fuel. This economic and engineering appraisal will be Phase III of this study.

5.2 Effect of the Absence of Lighter Boiling Components in Synthetic Crude Oil Samples

Lighter boiling components which are particularly needed to make JP-4 were absent from the kerosene fraction of many synthetic crude samples as shown in Table 5-1, on which inspections are shown for the "kerosene" feed fractions which were distilled from the synthetic crude oil samples. It is not clear whether the absence of lighter-boiling components within the kerosene fraction of most of our synthetic crude oil samples is the normal consequence of the particular processes employed for the production of the synthetic crude oils. Since we dealt with only one sample from each producer, it is not possible to judge the degree to which a particular sample may represent normal operation.

On the other hand, we are aware that in many of the developmental synthetic crude facilities now in operation, gases and light liquids which may be evolved in a process are used to fuel the plant, or simply escape because collecting facilities are non-existent or only partially effective. This is especially true for several of the developmental shale oil facilities located at high altitude, where the situation may be aggravated by prolonged storage of product oil in heated tanks at conditions conducive to accelerated weathering.

TABLE 5-1

IBP to 563 F FEED FRACTIONS

	Paraho	Tosco II	Garrett	Synthoil	H-Coal (as rec'd.)
ASTM Distillation					
IBP, F	373	220	311	222	177
5 Percent	413	273	385	404	212
10	426	294	404	416	234
20	446	320	434	428	268
30	462	347	450	443	297
40	475	372	461	458	328
50	486	399	469	468	356
60	494	426	478	478	376
70	506	453	487	490	397
80	518	478	496	500	422
90	531	502	510	514	464
95	550	518	522	525	510
FBP	556	530	527	528	544
Density, GMS/CC @ 60 F	0.8241	.0.8247	0.8565	0.9262	0.8567
Mass Spectroscopy					
Paraffins	33.2	25.8	35.9	0.5	1.4
Monocycloparaffins	4.6	28.3	5.9	38.8	43.4
Dicycloparaffins	11.3	9.3	10.5	8.5	8.3
Tricycloparaffins	10.2	6.4	8.4	0.0	1.6
PARAFFINS, Total	59.3	69.8	60.7	47.8	54.7
Alkylbenzenes	18.4	17.0	16.5	21.2	24.2
Indans	11.6	7.9	10.7	21.4	17.2
Indenes	5.0	2.7	4.1	7.7	0.2
Naphthalenes	5.2	2.3	7.6	1.6	3.2
AROMATICS, Total	40.2	29.9	38.9	51.9	44.8
Sulfur, Total Wt. Percent	0.8200	0.7600	0.6300	0.1000	0.5500
Nitrogen, Total Wt. Percent	1.3700	0.8700	1.0700	0.3000	0.1200
Yield on Whole Crude Oil					
Weight Percent	11.74	23.02	25.46	23.35	--
Volume Percent	12.77	26.09	27.15	26.46	—

In the design of commercial facilities, the value of the product fraction(s) will dictate the level of investment in hardware justified for the collection of that fraction. But shale oil production will, in large measure, occur at high altitude in remote, dry areas. The fuel that will power the facilities will necessarily be derived from the shale oil product. Designers will want to usefully consume generated fuel gases. The lack of cooling water, the high relative cost of power, or high operating costs for air-fin cooling, and the low ambient pressure will all combine to make containment or separation of volatile liquid components expensive.

It may develop, therefore, that shale oil product from a commercial facility will not differ significantly in composition from that produced by the developmental installation. In any case, it should be possible to generate additional light ends by operating on the heavier shale oil fractions by coking or cracking processes. The ultimate value of the desired fraction will dictate the extent of facilities provided to collect that fraction, assuming it is present in the product stream, or to generate that fraction from additional product. It is important at this point to caution against extrapolation of our yield observations from single developmental samples to commercial performance.

On the basis of the information developed for the samples we did receive, however, the TOSCO II feed would appear to have been the most desirable for aviation turbine fuel production on the basis of reasonable yield of a kerosene fraction from the whole crude which contained low levels of aromatics and of nitrogen, and from which both narrow- and wide-cut fuels could be prepared.

The Garrett shale oil exhibited a slightly higher yield of IBP-563°F material, but this kerosene fraction was higher in nitrogen and aromatics content, and was more dense, than the TOSCO II sample, such that wide-cut jet fuels could not be prepared. On the other hand, the Garrett whole crude sample produced the highest yield of IBP-650°F material among the shale oils, leading by a substantial margin over the TOSCO II sample (see Tables 3-1 to 34).

5.3 Discussion of Results by Synthetic Crude Type

5.3.1 Paraho Shale Oil Results

The results obtained in our Paraho hydrotreating experiments (see Table 4-2) appear to be consistent. The density of hydrotreater effluent decreased as severity increased. So too did the aromatics levels of the products. It would appear that there is no difference, however, in aromatics levels between the two high-severity (doubly hydrotreated) runs, or that aromatic levels cannot be reduced much below about 2 percent.

Nitrogen content, similarly, was reduced in regular fashion down to a level of about 40 ppm, which required something more than our normal severity conditions to achieve. However, the nitrogen content was unaffected, thereafter, by repeated hydrotreatment at high severity.

The sulfur content of Paraho shale oil was readily removed, even at our low-severity conditions. The slight variation in sulfur level shown is within the precision interval of the equipment used to measure sulfur content, but may additionally be due to incomplete stripping of hydrotreater effluent samples.

The Jet A fuels blended from hydrotreated stocks were thermally more stable than commercial jet fuels (excepting that fuel produced from low-severity product). Jet A fuels blended from the normal-severity product met all specifications, even though the particular result shown in Table 4-7 does not meet the freeze-point specification. This is a consequence of the trial- and- error procedures used to maximize yield of final finished fuel from hydrotreater effluent. In the case shown, more than 90 percent of hydrotreater effluent went into the final fuel, whereas a prior test blend, into which several percent less was incorporated, did meet the freeze point specification.

On the basis of results obtained, Paraho shale oil appears to be desirable feed for production of narrow-cut aviation turbine fuel. Its major disadvantages are the small yield of kerosene boiling-range components and/or the absence of light ends.

5.3.2 TOSCO II Shale Oil Results

The results obtained in our TOSCO II hydrotreating experiments (see Table 4-8) are generally consistent. Note again that TOSCO Feed A was additional feed distilled to have properties identical with the original kerosene feed fraction, and included all material in the original crude shale oil boiling up to 563°F. TOSCO Feed B included all material in the original crude shale oil boiling up to 650°F.

The aromatics content, sulfur content, and nitrogen content of Feed A are all essentially equal to that of the original feed fraction. Consequently, the density deviation is difficult to understand. The distillation data, too, are remarkably consistent.

The density of hydrotreater effluent appears to have reached a lower limit at the normal-severity conditions, as has the nitrogen content. Sulfur content is apparently at its lowest point at low-severity. In fact, except for aromatics level, which appears to be reduced in regular fashion through the high-severity run, there is probably good reason to consider the Product 410 results dubious.

The experiments conducted with TOSCO Feed B are quite consistent throughout, nowever. Density, aromatics level, sulfur, and nitrogen are clearly reduced as severity is increased at the high-severity base by reducing liquid hourly space velocity. It would appear that both nitrogen and sulfur compounds present in the higher boiling fractions are more refractory than those in the lower-boiling fraction, however.

The JP-4's produced from hydrotreated TOSCO stocks (see Table 4-12) show consistent properties throughout, however. All were thermally stable products, including the fuel blended from the low-severity stock. Sulfur content is essentially constant, and nitrogen content is close to expectation.

The Jet A fuels produced from hydrotreated TOSCO stocks (see Table 4-13) also show consistent properties. Only the fuel produced from the low-severity stock does not meet the thermal stability criterion.

The final JP-4 produced from normal-severity stock (see Table 4-14) meets all specifications excepting freeze point. This again is a consequence of using all (100 percent) of the hydrotreater effluent from the normal-severity Run 17B in the preparation either of the final JP-4 or Jet A fuel blends. That is, the total hydrotreater effluent was distributed between the two final fuels, causing the freeze points of both the JP-4 and Jet A fuels (see Table 4-15) to miss specification. Earlier test blends, equivalent to using about 95 percent of the total hydrotreater effluent between the two fuels, had both comfortably met the freeze point specification.

TOSCO II shale oil appears to be quite desirable as feed for the production both of narrow- and wide-cut aviation turbine fuels. The yields of finished fuels were highest in this case.

5.3.3 Garrett Shale Oil Results

Consistency of the results obtained in the hydrotreating experiments with Garrett shale oil feedstocks is about on a par with that of the TOSCO II series (see Table 4-16). In the Garrett case, Feed Garrett A included all material in the original crude oil sample boiling up to 563°F, identical with the original kerosene feed fraction, Feed Garrett B included all material boiling up to 650°F, and Feed Garrett C included all material in the original shale oil sample boiling up to 700°F. Feed Garrett 103 was the final Jet A fuel blend prepared from hydrotreated stock from normal-severity Run 103, and was refed to the unit in high-severity Run 415.

The properties of Feed Garrett A are essentially equal to those of the original kerosene feed.

The sulfur and nitrogen levels of hydrotreater effluents from the low-, normal-, and high-severity Runs 115, 103, and 404, respectively, are probably invariant. That is, residual sulfur and nitrogen retained after the equivalent of low-severity processing appears not much affected by hydrotreating at increased severity. Aromatics levels, however, are apparently reduced in regular fashion at increasing severity.

In the wider-boiling Feed Garrett B series, the sulfur value for hydrotreater effluent from Run 406 appears spurious. Otherwise, all results appear consistent; and results for the Feed Garrett C series also appear to be quite regular. It would appear that using a wider-boiling feedstock does not materially affect the quantity of nitrogen left unconverted after hydrotreatment at high severity, but does serve to introduce sulfur compounds more refractory than are present in the kerosene-range material.

It is difficult, from a single test (Run 415), to know whether the residual nitrogen level is really reduced by repeated hydrotreatment.

The Jet A fuels prepared from hydrotreated Garrett stocks (Table 4-24) show reasonably consistent properties. All were indicated to be thermally stable except the fuel prepared from the low-severity operation.

The single JP-4 fuel (Table 4-23) prepared from hydrotreated Garrett stocks was likewise indicated to have high thermal stability. Somewhat inconsistently, the JP-4 final fuel was indicated to have higher sulfur content than the Jet A fuel prepared from the same base stock. In this case, however, as can be seen from the distillation data, both fuels had essentially the same endpoint, aromatics levels, and densities, a consequence of the necessity to "squeeze" to produce any JP-4 at all. Hence, the JP-4 blend itself is virtually an anomaly, and was prepared mainly to determine that it was possible to do.

The Jet A blend prepared from normal-severity Run 103 (Table 4-25) appears to meet all specifications except freeze point. In this case, the final fuel blend represents about 85 percent of hydrotreater effluent. A prior test blend representing about 80 percent of reactor effluent also missed the freeze point specification by about one degree Fahrenheit.

The Garrett shale oil may be desirable as feedstock for producing narrow-cut jet fuel, and would probably be suitable as feedstock for wide-cut jet fuel production if it were to contain slightly more lighter components. The original shale oil sample gave the highest yield of kerosene boiling-range material, as well as a significantly higher yield of IBP to 650°F material (see Table 3-3) than did the other shale oils.

5.3.4 Synthoil Results

The results obtained in our Synthoil hydrotreating experiments (see Table 4-26) appear to be consistent. The density of hydrotreater effluent decreased as severity was increased, as did the aromatics levels of the products. Sulfur and nitrogen levels did not appear to be materially affected through the normal-severity range of treatment. Note that the original feedstock, in this case, was produced in a hydrogen atmosphere at high pressure.

Based on a single test (Run 416), it would appear that nitrogen and aromatics levels can be materially reduced by a second hydrotreatment. Interestingly, the density of hydrotreater effluent from the repeated hydrotreatment is within shooting distance of the specification density for Jet A type fuel, and the final fuel blended from this run (Table 4-32) does meet the density specification.

Again, based on a single comparison (Product 202 versus Product 105), it would appear that the cobalt-molybdenum catalyst used was less active, resulting in less severe hydrotreating performance than nickel-molybdenum, at comparable physical parameters. That is, the hydrotreater effluents from the two runs appear to be essentially equivalent, but required a hold time about 17.0 percent higher for cobalt to achieve compared with nickel at 1500 psig. The two nickel Runs 107 and 105 similarly represent a hold time difference of 17.0 percent, but show a significant difference in severity.

It was interesting to find that all Jet A products blended from Synthoil stocks excepting that produced from low-severity Run 203 met the thermal stability criteria (Table 4-32). The fuel produced from cobalt Run 202 was only marginally passing, however. We note here, and elsewhere, that quite small differences in the amounts of high-boilers included in the final fuel blend could cause significant swings in important properties without adding, or subtracting, materially from overall yields.

The Jet A final fuel blends prepared from Synthoil stocks (Table 4-33) did not meet smoke point specifications, aromatics content specifications, or density specifications. There was insufficient material, however, to obtain additional inspections for the Jet A fuel blended from the doubly-hydrotreated Run 416, which did meet the density specification.

The Synthoil feedstock, except through more severe processing than is required for the shale oils, does not yield significant quantities of specification aviation turbine fuels of the types desired.

5.3.5 H-Coal Results

The results obtained in our H-Coal hydrotreating experiments (see Table 4-34) are less consistent than would appear from the table, due to operating difficulties continually encountered with this feedstock (see Section IV above). Because of build-up of reactor pressure drop almost immediately accompanying the feeding of H-Coal liquid into our system, it was very difficult to obtain the steady-state operating conditions desired for sample accumulation. Unlike the cases of other feedstocks, where the quantities of available feeds limited operating periods, H-Coal runs were almost always aborted due to high reactor pressure drop.

It is not clear why aromatics levels reduction appears consistent throughout, but density and boiling range appear reversed nevertheless for normal-severity Run 209 and high-severity Run 417. If real, this may indicate a desirable property of the cobalt catalyst relative to nickel for the hydrotreatment of dense coal liquids. Note that the H-Coal liquid all boiled in the kerosene range as received, and was not further distilled to produce feedstock for hydrotreatment. Moreover, the same feed was used in low-, normal-, and high-severity Runs 304, 209, and 417, respectively.

Repeated hydrotreatment at high-severity, based on a single test (Run 419), materially reduced aromatics level, and appeared to remove all sulfur.

The final JP-4 fuel prepared from normal-severity Run 209 (see Table 4-38) was thermally stable, as were the Jet A fuels prepared from normal-severity Run 209 and from the doubly-hydrotreated high-severity Run 419 (see Table 4-39). Neither the JP-4, nor Jet A, fuel prepared from low-severity Run 304 met thermal stability criteria.

The final JP-4 fuels prepared from both the *normal-* and *low-severity* operations meet all other specifications, however, excepting density (see Table 4-40). The final JP-4 produced from normal-severity Run 209 in particular would require only minor adjustment to meet this specification.

The final Jet A fuel prepared from normal-severity Run 209 meets all specifications except density and smoke point (see Table 4-41). The Jet A produced from the low-severity operation additionally does not make the aromatics specification.

Because of the operating difficulty incurred in the hydrotreatment of H-Coal liquid, considerable additional research is indicated to determine its overall desirability as feedstock for aviation turbine fuel production.

5.4 Discussion of Hydrotreating Process Variable Effects and Chemistry

Fixed-bed catalytic hydrotreating has been applied commercially to improve the qualities of straight-run and cracked naphthas, middle distillates, and gas oil fractions separated from natural petroleums for over twenty years. Such hydrotreated materials, in the current petroleum processing framework, may be used either in finished products, or as feedstocks for subsequent processing.

Generally, the purpose of hydrotreating is to eliminate one or more undesirable impurities, such as sulfur, nitrogen, or color precursors, from the feedstock. The processing conditions employed, including temperature, pressure, treat gas rate, and catalyst type and amount, all of which together determine the severity of hydrotreatment, are chosen to effect the required degree of impurity removal.

5.4.1 Discussion of Hydrotreating Process Variable Effects

Hydrotreating operating conditions needed to achieve the desired feedstock quality improvement vary considerably with the feedstock type. For a given feedstock, both the crude source and the conditions employed in its prior processing, especially if cracking processing were involved, can profoundly influence the severity of the hydrotreating conditions required.

Our objective in the hydrotreatment work was to ascertain whether specification jet fuels could be produced from the synthetic crude oil samples on hand. In no case, except coincidentally, did we optimize process conditions or catalyst type. Instead, our experimental matrix was designed to encompass the operating range of commercial refinery hydrotreating equipment, with view toward future long-term system optimization.

Similarly, our distillation treatment of feeds and hydrotreated product was chosen to approximate the minimum degree of handling that synthetic crude oils might encounter in blocked-out refinery operations. An obvious alternative to the prior separation of a kerosene fraction which is later hydrotreated, as in our work, is the prior hydrotreatment of the whole synthetic crude oil, followed by separation of the desired product, or of a product cut which may be subjected to additional treatment. Alternatives of this nature were clearly outside the scope of this study. This seeming infinitude of processing alternatives may be reduced to manageable proportions through future screening studies.

5.4.1.1 <u>Temperature</u>

Temperature is a fundamental variable in hydrotreating processing. In this study, the temperature at which experiments were conducted was invariant, held to 700°F (371°C). Typical commercial hydrotreating processing of natural petroleum fractions similar to those we treated is conducted in the range 550 to 750°F, so that our processing temperature was in the upper range of commercial conditions.

Temperature is an important, and normally convenient, process variable for controlling catalytic hydrotreating severity. As catalyst deactivates in the course of operation, reactor temperature may be increased to maintain product specifications. In our case, however, no catalyst batch was employed sufficiently long to cause material deterioration in activity requiring temperature change.

5.4.1.2 Treat Gas Rate and <u>Treat Gas Composition</u>

Treat gas rate, expressed as standard cubic feet per 42-gallon barrel of feedstock (SCF/B), was a variable we targeted to be held constant at 4000 SCF/B. Increasing treat gas rate results in a higher hydrogen partial pressure when other conditions - total pressure, temperature, and LHSV - are held constant.

The composition of treat gas obviously affects the hydrogen partial pressure, but the hydrogen content of our treat gas was essentially 100.0 percent (chemically pure hydrogen assaying a minimum of 99.999 percent was employed throughout). Hence, deviations from the targeted treat gas rate, caused largely by virtue of the differences in density of the many feeds employed, had only small effect on the hydrogen partial pressure in the reactor.

Commercial treat gas rates for similar processing range from about 500 to 5000 SCF/B, so that our target condition was again at the high end of the commercial range.

5.4.1.3 Reactor Pressure

Our operations were conducted at three total pressures: 1500 psig, 800 psig, and 2200 psig. Reactor pressure is frequently reported as the average of the inlet and outlet pressures of the reacting system. In our case, excepting for certain runs conducted while excessive reactor pressure drop was being encountered (generally limited to the H-Coal operations; see Section IV), the difference between inlet and outlet reactor pressures was observed to be less than the precision interval of our pressure measuring equipment (± 10 psi at 2200 psig).

Increases in reactor pressure tend to increase hydrotreating severity. The total pressure exerts an important influence on the capital cost of hydrotreating equipment, and on the operating costs as well. Commercial hydrotreating equipment for similar feeds is operated at pressures between about 250 and 1500 psig. Hence, 1500 psig represents moderately severe commercial practice, and 2200 psig is beyond the commercial range for these types of feedstocks.

5.4.1.4 Space Velocity

Space velocity is a measure of the time the feedstock is in contact with the total volume of catalyst in the reacting system. The liquid hourly space velocity (LHSV) is reported as the volume of liquid feed per hour per total volume of catalyst in the reactor. Hence, the holding time, in hours, is 1/LHSV.

Increasing the contact time by lowering the space velocity increases the severity of hydrotreating. Commercial hydrotreating practice for similar feedstocks encompasses the range of liquid hourly space velocities from about 0.5 to about 3.0. Our normal LHSV of 1.0 is thus about in the middle of the commercial range, and our high-severity LHSV of 0.5 is at the upper end of commercially-employed hold times.

5.4.2 Chemistry of Hydrotreating

The two main chemical reactions which occur in hydrotreating involve the conversion of sulfur to hydrogen sulfide, and the conversion of nitrogen to ammonia. The hydrogen sulfide and ammonia gaseous products are relatively easily removed from the hydrotreater liquid effluent by subsequent pressure reduction and/or stripping.

Among the many other types of reactions which may occur in hydrotreatment, two of the more significant are the conversion of olefins to paraffins, and the hydrogenation of oxygen-bearing compounds. Of the four types of reactions mentioned here, however, that of sulfur removal invariably dominates when virgin, or unprocessed, feedstocks are involved. Olefin saturation, nitrogen elimination, and the hydrogenation of oxygenated materials may be major considerations for some pre-processed, especially cracked, feedstocks. For certain stocks, an additional important reaction type is the hydrogenation of aromatic compounds to yield naphthenes and paraffins.

Examples of these reaction types are shown in Figures 5-1 through 5-3. Figure 5-1 illustrates three of the major classes of sulfur removal reactions. However, at least thirteen major classes of sulfur compounds have been identified in petroleum oils, including some two hundred specific compounds boiling in the temperature range of interest in this study.

Figure 5-3 illustrates only single examples of denitrogenation, deoxygenation, and of olefin saturation. The possible reactions in each of these categories is myriad.

Some commercial feeds, especially certain cracked naphthas, contain diolefins. The saturation of these diolefins is a major function of hydrotreating, since the competing reaction, that of dimerization, leads to gums which foul subsequent processing equipment. Figure 5-3 illustrates the desired saturation hydrotreating reaction type along with the undesired dimerization reaction.

Note that hydrogen is "consumed" in all of the above-illustrated reactions, and is consumed also in the numerous other reactions which may occur in hydrotreating. The amount of hydrogen which disappears in the reactor depends on which reactions are occurring, which in turn depends on feedstock properties and on the processing conditions being used.

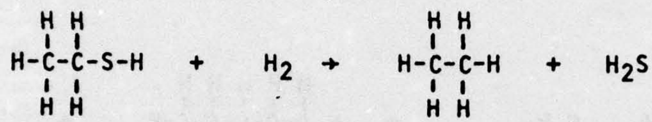
5.5 The Effect of Hydroprocessing Severity on Jet Fuel Product Composition

In general, changes in the product composition were directly related to hydrotreatment severity for a given synthetic crude material. In Table 5-2 is summarized some of the data obtained in the effect of low severity processing (800 psig), normal severity processing (1500 psig) and high severity processing (2200 psig) on the sulfur and nitrogen remaining in the treated product. The sulfur and nitrogen levels present in the feed material are shown for comparison purposes. Some reservations must be made in attributing all changes to the effect of pressure, since in some cases concurrent changes were made in space velocity and catalyst type in addition to the change in hydroprocessing pressure. In general, sulfur and nitrogen levels were drastically reduced by catalytically hydroprocessing. The total sulfur levels of even the mild severity hydroprocessed shale and coal liquids were all below 100 ppm, which is much lower than the current 4000 ppm total sulfur specifications for JP-4 and the 3000 ppm total sulfur specifications for Jet A. Sulfur removal, thus, would not appear to be a problem at any processing severity. With the Tosco and Paraho above ground retorted shale oil, nitrogen removal was generally more difficult than sulfur removal, as has been reported by other investigators. Even with severe hydroprocessing the nitrogen levels of all the shale oil products did not go below 40 ppm, which is considerably higher than the nitrogen levels of present petroleum derived jet fuels, e.g. 1-5 ppm. Severe and multiple hydroprocessing of

FIGURE 5-1

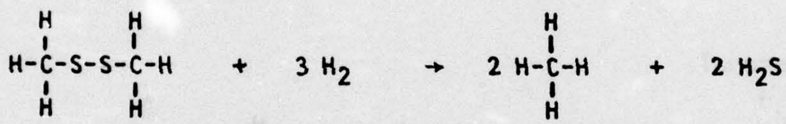
Sulfur Removal Reactions in Hydrotreatment

1. Removal of Mercaptan Type Sulfur



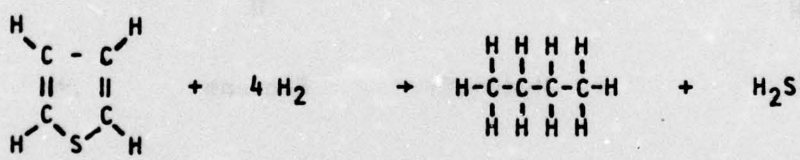
Ethyl Mercaptan + Hydrogen → Ethane + Hydrogen Sulfide

2. Removal of Disulfide Type Sulfur



Methyl Disulfide + Hydrogen → Methane + Hydrogen Sulfide

3. Thiophenic Sulfur Removal

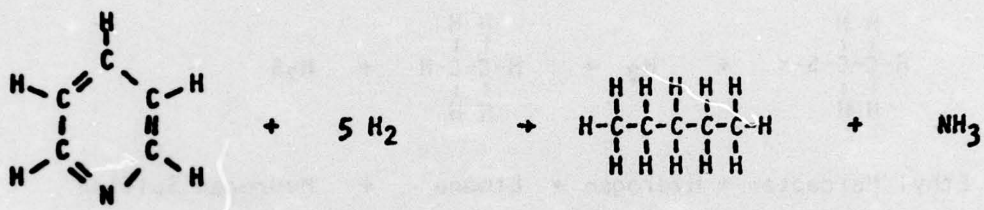


Thiophene + Hydrogen → Butane + Hydrogen Sulfide

FIGURE 5-2

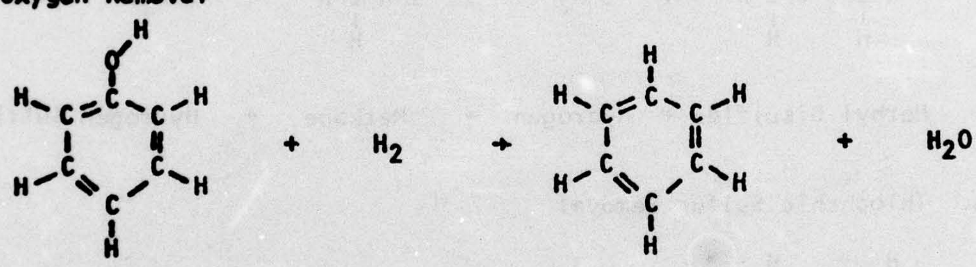
Denitrogenation, Deoxidation, and Olefin Saturation Reactions in Hydrotreatment

4. Nitrogen Removal



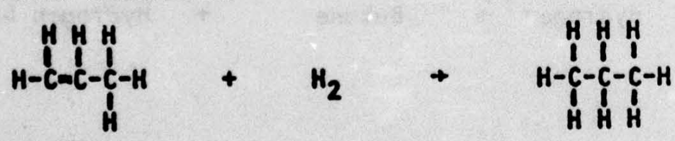
Pyridine + Hydrogen → Pentane + Ammonia

5. Oxygen Removal



Phenol + Hydrogen → Benzene + Water

6. Olefin Saturation

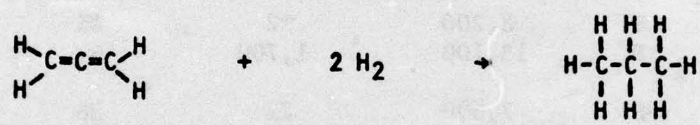


Propylene + Hydrogen → Propane

FIGURE 5-3

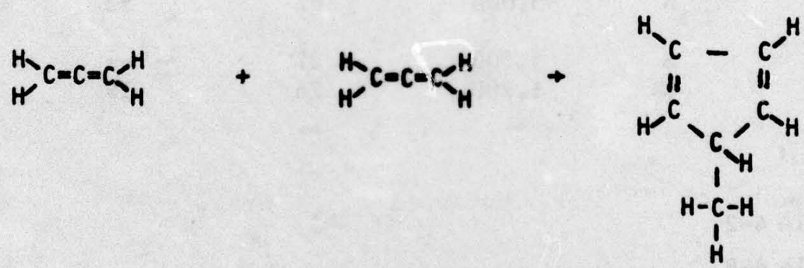
Diolefin Saturation vs Dimerization Reactions in Hydrotreatment

7. Diolefin Saturation (Desirable)



Propadiene + Hydrogen → Propane

8. Diolefin Dimerization (Undesirable)



Propadiene + Propadiene → Methylcyclopentene

coal liquids (in themselves already hydroprocessed in the crude preparation step) produced products with a low nitrogen level, i.e. < 1 ppm. Nitrogen levels generally decreased with increased severity for both shale oil and coal oil liquids.

TABLE 5-2

Summary of the Effect of Hydroprocessing Severity on Sulfur and Nitrogen Removal

Crude Type		S or N Present, ppm: Kerosene Feed to Unit	Processed Product: Low Processing Severity	Normal Processing Severity	Severe Processing Severity
Paraho Shale Oil[1]	S	8,200	2	11	21
	N	13,700	1,700	67	40
Tosco II Shale Oil[2]	S	7,600	22	36	74
	N	8,700	200	20	41
Garrett Shale Oil[3]	S	6,300	49	51	33
	N	10,700	42	74	55
Synthoil Coal Oil[4]	S	1,000	12	31	< 1[6]
	N	3,000	62	53	< 1[6]
H-Coal Coal Oil[5]	S	5,500	27	--	26
	N	1,200	26	19	< 1

[1] From Table 4-2

[2] From Table 4-8

[3] From Table 4-16

[4] From Table 4-26

[5] From Table 4-34

[6] Hydroprocessed twice

In Table 5-3 is shown a summary of the effect of hydroprocessing severity on the distribution of the main compound classes, i.e. aromatics, paraffins and naphthenes (cycloparaffins) in the treated product. The corresponding data in the synthetic feed material is shown for comparison purposes. The paraffin, aromatic and naphthene (PAN) distribution of the crude shale oil kerosene fraction is much closer to that of a petroleum derived material than the coal-derived kerosene since the coal derived crude kerosene contains practically no paraffins (i.e. 0.5 & 1.4%). For both the shale and coal derived kerosene, increasing the severity of hydroprocessing increased the conversion of aromatics. With the shale liquid, hydroprocessed product paraffin content remained essentially the

TABLE 5-3

Summary of the Effect of Hydroprocessing Severity on Compound Class Distribution, i.e. Aromatics, Paraffins and Naphthenes (Cycloparaffins)

Crude Type	Composition by Mass Spec Analysis	Kerosene Feed to Unit	Processed Product: Low Processing Severity	Processed Product: Normal Processing Severity	Processed Product: Severe Processing Severity
Paraho Shale Oil[1]	Aromatics	40.2	23.5	----	1.6
	Paraffins	33.2	47.5	----	47.7
	Naphthenes[7]	26.6	30.0	----	50.7
Tosco II Shale Oil[2]	Aromatics	29.9	19.3	7.5	2.1
	Paraffins	25.8	50.3	51.8	52.0
	Naphthenes[7]	44.3	30.4	40.7	45.9
Garrett Shale Oil[3]	Aromatics	38.9	21.5	12.1	4.8
	Paraffins	35.9	47.1	48.3	47.4
	Naphthenes[7]	25.2	31.4	39.6	47.8
Synthoil Coal Oil[4]	Aromatics	51.9	50.2	24.0	1.6
	Paraffins	0.5	1.4	8.2	15.9
	Naphthenes[7]	47.6	48.4	67.8	82.5
H-Coal Coal Oil[5]	Aromatics	44.8	35.7	20.2	2.9
	Paraffins	1.4	5.0	10.0	4.6
	Naphthenes[7]	53.8	59.3	69.8	92.5

[1]From Table 4-2
[2]From Table 4-8
[3]From Table 4-16
[4]From Table 4-26
[5]From Table 4-34
[6]Hydroprocessed twice
[7]by Difference

same at all processing severities, indicating that the aromatics are being hydrogenated selectively to naphthenes without any extensive ring cracking to produce paraffins. A similar, but not as pronounced a trend, is seen with the coal liquids. Thus, in general, hydroprocessing with the catalysts employed in this study will hydrogenate the aromatics to naphthenes, with an increasing processing severity simply increasing the amount of aromatic conversion.

A comparison of the PAN distribution of the hydroprocessed shale oils versus coal oils shows the following:

1. Mild hydroprocessing produces acceptable (i.e. less than 25%) aromatic levels with shale liquids, but normal severity processing is necessary to reach the same aromatic levels with coal liquids.

2. Coal liquids have very low paraffin levels at all processing severities and thus in general have a different PAN distribution than petroleum-derived jet fuels. This results in the following general effects on density, luminometer number, freeze point and heat of combustion:

   - Density - For a given carbon number aromatics have higher densities than naphthenes, which in turn have higher densities than paraffins. Thus, for a fixed aromatic level, a coal-derived fuel will have a higher density than a shale or a petroleum-derived fuel. To achieve the same lower density with coal liquid derived fuel, other measures must be taken such as (1) lowering the total aromatic level or (2) reducing the amount of higher carbon number naphthenes (and paraffins to the extent that they are present).

   - Luminometer Number - For a given carbon number, in general, paraffins have a higher luminometer number than naphthenes which have a higher number than aromatics. Thus, for a fixed aromatic level, a coal-derived fuel will have poorer combustion properties than a shale oil or petroleum-derived fuel. In general, increasing the carbon number of paraffins and naphthenes lowers the luminometer number. Thus, to improve the combustion properties of a coal-derived fuel will require measures such as (1) a reduction in total aromatics relative to that present in a petroleum or shale oil-derived fuel and (2) reducing the amount of higher carbon number naphthenes (and paraffins to the extent that they are present).

- Freeze Point - The much lower level of paraffins in a coal-derived jet fuel will result in a lower freeze point than a shale oil or petroleum-derived fuel. To lower the freeze point of a shale oil-derived jet fuel, the higher carbon number paraffin content of the fuel must be reduced.

- Heat of Combustion - For a given carbon number aromatics have a higher volumetric heat of combustion than naphthenes - which are higher than paraffins. The weight heat of combustions are in the inverse order. Thus for a fixed aromatic content a coal-derived fuel will have a higher volumetric heat of combustion and a lower weight heat of combustion than a shale oil-derived fuel.

5.6 Extrapolation of Results

The present study with synthetic crude feedstocks generated only limited pilot plant data when compared to the much larger base of pilot plant and commercial data available relative to processing petroleum-derived feedstock. Thus, the use of these pilot plant results to make judgments regarding commercial synthetic processing results is obviously subject to greater uncertainty than would be with petroleum-derived data. In the processing of natural petroleum feedstocks, quite elaborate systems of correlations are used to predict changes in processing conditions required to achieve desired quality improvement when feedstock type is varied, for example, or when catalyst type or quantity is changed, or to predict the effect, generally, of one change in an operating variable on the changes required in the other variables to maintain the activity of the reacting system. Even the simplest apparent reaction, however, is found under investigation to proceed in quite complex and in generally indeterminate fashion, such that all such correlations are generally limited in practice to cases which fall inside the ranges of feedstocks and operating variables used to obtain the data which were correlated. And the data are frequently found to be a function of the hardware employed to generate them, such that even extrapolation from pilot plant to commercial unit involves additional correlating factors.

Moreover, the hardware systems employed commercially for hydrotreating generally represent such large capital investments, and incur such high operating costs, that there is extreme reluctance on the part of operators to deviate from demonstrated performance, let alone extrapolate to feedstocks or conditions outside the range even of the pilot-plant data. Generally, the commercial plant operator is looking for assurance based on replete pilot-plant experience before considering a major change in feedstock type or significant deviation from previous operating conditions. Pilot-plant runs extending for months, or for significant fractions of a catalyst's lifetime, are normally expected in connection with such projected major changes.

It was not possible with the limited quantities of synthetic feed available to this program, to come to meaningful conclusions regarding catalyst behavior, yield maintenance, or to estimates of catalyst life. More than 900 hours of hydrogenation operation were accumulated on one nickel-molybdenum catalyst bed over a 1700-hour period, for example, with very little change in activity, as indicated by the reduction in aromatic content of a commercial JP-5 aviation fuel feed. On the other hand, periods during which synthetic feeds were being run represented less than 10 percent of the total operating time, and it was necessary to change out the catalyst at the end of this period because the catalyst bed had developed a high pressure drop, notwithstanding its apparent high activity. Attempts to feed H-Coal liquid, especially, were accompanied by very rapid increase in catalyst bed pressure drop in our system over both nickel-molybdenum and cobalt-molybdenum catalysts, causing abortive run terminations and unit shutdowns. This tendency could not be explained in terms of the physical and chemical determinations which were obtained normally for all of our feeds and products, and it was not possible to expand our search for causative factors in this program.

Our results do establish, however, that specification aviation turbine fuels can be produced from all of the shale oil feeds. Moreover, it is probably possible to produce fuels from the synthetic coal liquids which meet all specifications excepting density using our procedures. In fact, the synthetic Jet A fuel produced from Synthoil Run 416, which represented doubly hydrotreated material, does meet the density specification for this fuel type (0.830 max).

Consideration of the data for the properties of some of the synthetic fuels prepared in this program will indicate that once-through hydrotreatment at our low-severity conditions will generally result in unacceptable or marginal products. The minimum degree of once-through treatment which produce an acceptable product is most often indicated to lie between the low- and normal-severity conditions for the shale oils, and above the normal severity conditions for the coal liquids. An operating regime which remains to be explored is the repetitive and/or liquid recycle treatments, and especially the relationship between severity and repeated hydrotreatment.

In general, acceptable JP-4 type fuel could be produced using a lesser degree of hydrotreatment, when it could be produced at all, than was required to permit blending of an acceptable Jet A fuel from a given hydrotreated product. For example, JP-4 blended from the low-severity hydrotreated TOSCO Run 113 product was given an acceptable rating in the JFTOT thermal stability test, whereas the Jet A blended from that same hydrotreated product was found to be unacceptable. Another obvious area for future exploration involves separation of acceptable wide-cut fuel product from hydrotreater effluent, with recycle, or secondary hydrotreatment, of the narrow-cut heavier material.

SECTION VI

CONCLUSIONS

Specification aviation turbine fuel can be produced from shale oils by catalytic hydroprocessing of the kerosene fractions of the crude shale oil if the proper processing severity is employed. It is much more difficult to produce specification turbine fuels via similar catalytic hydroprocessing of coal liquids fractions. These results confirm the conclusions made in the Phase I portion of this program that shale liquids would be more suitable for jet fuel production than coal liquids. This difficulty with producing turbine fuels from coal liquids results from the following two factors: (1) the basic chemical composition of coal liquids is that they are high in aromatic and low in paraffins and (2) typical hydroprocessing catalysts convert the aromatics to naphthenes without substantial ring opening (cracking) to produce paraffins.

The synthetic crude samples evaluated in several cases tended to be low in lighter boiling material. Such an absence of light ends will make it difficult to produce wide-cut aviation turbine fuels via simple fractionation followed by catalytic hydroprocessing. In such cases, the processing of heavier fractions to produce higher yields of lighter components using a process such as catalytic hydrocracking may be desirable.

Hydroprocessing severity is important in the production of specification turbine fuels. Production of specification fuel from shale liquids will require at least a moderate severity operation employing a 1500 psi total pressure. Increased processing severity in general improved thermal stability and decreased the aromatic and nitrogen content of this product fuel. Even severe hydroprocessing, however, did not reduce the nitrogen levels of shale liquids below 40 PPMN, which is much higher than found in present day petroleum derived jet fuels. Since nitrogen compounds are known to exert a deleterious influence on the storage and thermal stability properties of jet fuels, the level and types of such compounds present in fuel prepared from shale crude will be an area for concern. Sulfur levels of the processed fuels were well below specifications at all processing severity levels.

APPENDIX I

HYDROGENATION SYSTEM START-UP PROCEDURES

A1.1 Pressure Testing

The unit will be pressure tested with nitrogen or helium after each extended shutdown period. Pressure will be 3000 psig or 90% of the relief valve settings for individual sections of the unit, whichever is lower. A final hydrogen test at operating pressure will be conducted as the last step before startup. This final test should not include the liquid-filled systems.

A high pressure nitrogen test will be conducted on the tubular reactors and/or autoclave whenever catalyst is changed in these vessels. The only exception to this is when the catalyst has been changed after an extended shutdown and the unit, including the reactors, has been helium tested.

A1.2 Hydrogen Feed System

Practical operating experience has shown that the best performance of the Aminco compressors is achieved when they are not depressured. Therefore, prior to startup of the H_2 system, inlet valves 208 and 210 and outlet valves 212 and 215 will normally be closed with gas pressure between them.

Open the H_2 manifold and set the manifold regulator at 500 psig. Open valves 201 and 203 and close bypass valve 202. Pass gas through compressor inlet filter 13 or 14 by opening the appropriate inlet and outlet valves and closing the vent valve. Valves on the filter not in use should be in the opposite positions. Open Compressor 1 inlet valve (208) and start compressor by opening air to compressor drive. Pump up to 5000 psig against a closed discharge valve (212) to make certain the compressor is operable. At 5000 psig open valve 212 and allow gas into Accumulator. Repeat this procedure with Compressor 2. Set high and low Accumulator pressure limits on pressure switch 42. The high limit will shut off the compressors and the low limit will start them. Normally, the high limit will be set at reactor pressure plus 2000 psi and the low limit at reactor pressure plus 1000 psi.

The Accumulator serves as a gas pressure source for three systems: the liquid feed blowcase, the additive blowcase, and the PVT tanks. The pressure supplied to each system is controlled by Hoke downstream regulators. The regulators on H_2 to the additive and liquid feed blowcases (HR-201 and 202) should be set 500 psi above reactor pressure. HR-203, the regulator of the H_2 feed line to the PVT tanks should be set 1000 psi above reactor pressure. The PVT tank not in use is always the tank being filled. Pressure switches 15 and 16 determine which PVT tank is being filled.

A1.3 Liquid Feed System

Set N_2 pressure on the feed tanks at a setting sufficient to maintain at least 6 psig upstream of the filter systems. Open one branch of each filter system on the suction side of the feed pumps. The other branch of the filter systems should be kept closed so that a clean filter is always available. After checking that calibration valves 123 and 135 are closed and that recycle valves 122 and 134 are open, start both feed pumps. Pump against closed discharge valves 126 and 138. Set pump recycle Mity-Mites (MM-1 and 2) at 500 psi above liquid feed blowcase pressure. If pump discharge pressure does not come up quickly to Mity-Mite pressure, bleed the pump heads to remove any trapped air. When pumps are operating satisfactorily, open the pump discharge valves to allow liquid feed to flow through control valves RV-1 and 2 and into the feed blowcases. Blowcase bypass valves V-141 and 142 should be kept closed, as should crossover valve V-128, during normal operation. Liquid feed will fill the blowcases until the levels reach the control range, as measured by the Drexelbrook capacitance probes. Control valves RV-1 and 2 will then close, forcing the pump outputs to be recycled back to pump suction. Thereafter, RV-1 and 2 will open only partly to allow as much liquid feed in as is being removed by the liquid feed systems.

A1.4 Starting Stream Flows

After filling all of the feed tanks and blowcases, the next step should be to determine reactor configuration. If the "parallel" (Sandbath reactors in series, Autoclave in parallel) configuration is chosen, the alarm system switch must be turned to the parallel position, valves V-800 and 1100 must be opened and valves V-801 and 1101 closed. Valves V-802 and 806 should be opened so that the pressure drop across Sandbath 1 is measured by ΔP cell PI-4. Sandbath 2 pressure drop is determined as the difference between total drop (Heise Gauge 1 minus Heise Gauge 2) and the drop across Sandbath 1. Set PIC-1 at the desired Sandbath reactor pressure. PIC-2, the Autoclave pressure controller, should be set at the desired Autoclave pressure. Theoretically, this does not have to be the same as the Sandbath pressure; however, in practice, differences in these pressure settings lead to control problems.

Turn the fluidizing air on to both Sandbaths and raise them by adjusting the spool valve on the panel board. Set the Sandbath temperature controllers to the desired temperature. Turn on the Autoclave heater and set the Foxboro temperature controller at the desired setting. Make certain that Autoclave cooling water is open.

To start the H_2 feeds, set regulator HR-204 at 500 psi above the reactor pressure and the control loop back-pressure regulators, MM-3, 4, and 5, at 100 psi above the reactor pressure. Open one branch of the filter system on each of the H_2 feeds to be used. Set the Foxboro controllers, FIC-3, 4, and 5 at their respective set points. Open valve V-247 and close V-246 and 248 to preheat H_2 feeds to Sandbaths 1 and 2.

When the reactors are up to control pressure and excess H_2 is being vented, as indicated by the wet-test-meters, start the flow of liquid feed to Sandbath 1 and the Autoclave. This is accomplished by opening one branch of each of the liquid feeds and setting the Foxboro controllers, FIC 1 and 2, at the desired set points. Liquid feed may also be preheated by opening valves V-158 and 160 and closing V-159 and 161.

Additive feed to the Autoclave is started by opening V-408 and setting FIC-7 at the desired set point. Additive feed to Sandbath 1 is initiated by opening the suction and discharge valves and starting the Ruska pump. The proper gear sets must be chosen to give the desired feed rate.

In the "parallel" configuration, if recycle is desired, start the Zenith recycle pump when liquid effluent from Sandbath 2 first appears in Liquid Receiver 1. Start the pump with the recylce flow controller (FIC-6) at 0 and slowly bring the rate up to the setpoint.

APPENDIX II

HYDROGENATION SYSTEM OPERATING PROCEDURES

A2.1 Access to the Cell

The operating philosophy for this unit divides the cell into three types of areas.

- Class A (Routine). Daily maintenance operations. While in a Class A area the operator has semi-permanent 1/2" plexiglass shielding from entire unit, except Class B equipment, and sliding door protection from other Class A and all Class B equipment.

- Class B (Routine but Infrequent). The same shielding requirements as Class A. The primary difference between Class A and B is the need to depressure equipment before opening sliding doors when working in a Class B area.

- Class C (Unforeseen). There is no shielding from other Class C equipment. Because of this lack of shielding, permission of the site safety engineer is required to enter this area during operation.

A2.2 Routine Maintenance

Trouble-free operation of orifices, control valves, regulators, etc. depends upon clean, particle-free fluid streams. To ensure this type of fluid streams, a large number of filters have been incorporated into the system. These filters must be cleaned periodically. To facilitate this operation, all of the primary filters consist of 2 filters in parallel, each with its own inlet and outlet block valves, pressure gauge and vent. To change filters, close the vent valve of the filter to be put into service and open the inlet and outlet valves. The pressure gauge should come up to and hold at line pressure. After opening and verifying operation of the replacement filter, shut the inlet and outlet valves of the old filter and then open the vent valve. Verify the depressuring of the filter with the gauge before removing filter.

A2.3 Sampling

Seven sampling points are available for the unit; three from Sandbath 1, one from the knockout tank between Sandbaths 1 and 2, two from Sandbath 2, and one from the Autoclave. Each sample line has an inaccessible Nupro needle valve to limit sample flow to a safe level. The point to be sampled is selected by opening one of the seven block valves at the sampling system. The selected stream is depressured into a N_2 purged glass tee and from there drains into a vial. All sample lines have been made from capillary tubing to reduce sample holdup.

APPENDIX III

HYDROGENATION SYSTEM SHUTDOWN PROCEDURES

A3.1 Normal Shutdown

To ensure a normal, operator-controlled shutdown rather than having the first step of the normal shutdown cause an emergency shutdown, dial out the alarm system. In most cases, this involves setting the low pressure switch at less than 3 psi. Do not change the settings of any of the 8 control pressure switches.

A. Overnight Shutdown

Any shutdown which will not involve the removal of the catalyst will be considered an overnight shutdown. Shut off Zenith recycle pump, if in use, and close valves on inlet and outlet of recycle system (V-700, 701A, and 701B). If the shutdown is for more than a weekend, drain the system using the drain on the inlet filter system. Next cool reactors. Slowly depressure reactors by reducing setpoints on PIC-1 and 2 in small increments. Leave several hundred psi pressure on reactors to prevent getting air into system.

B. Prolonged Shutdown

If catalyst is to be removed from reactors, shut off liquid feed systems. Purge system with H_2 for 15 minutes to remove liquid from the reactors. Do not purge longer than 15 minutes as this may blow catalyst dry and make it hazardous to handle. Depressure reactors to atmospheric pressure. Drain blowcases and manually depressure Accumulator, PVT tanks, blowcases, and product receivers.

A3.2 Emergency Shutdown

An alarm and emergency shutdown system has been provided on the unit. In the "parallel" position, three types of alarms are possible:

- Autoclave alarms
- Sandbath alarms
- System alarms

Autoclave and Sandbath alarms shut down their respective subsystems without interfering with the other subsystem. System alarms, such as instrument air failure or cooling water failure, shuts down the whole unit. Power failure also shuts down the entire unit, though not explicitly considered an alarm condition since the alarm system also fails. In the "series" position, all alarms shut down the entire unit.

The alarm system consists primarily of pairs of pressure switches. One switch of the pair is the high alarm and one is the low alarm. The switches measure the pneumatic signal pressure from the flow, pressure or level measurement devices. Once the variable has reached a steady-state condition, the high switch should be set 2-3 psi above the pneumatic signal and the low switch 2-3 psi below. If the variable goes off steady-state conditions to one of the switch settings, an alarm condition is signaled and the part of the unit affected is shut down. The table on the following page shows the alarm conditions and the actions taken sequence. The alarm panel indicates the presence of an alarm condition audibly and visibly. The audible alarm is shut off by acknowledging the condition which also changes the visual alarm from red to white. If more than one alarm condition occurs, only the first will be indicated by the visual alarm. Correction of the first alarm condition will cause an indication of the subsequent failure, provided it has not also been corrected.

APPENDIX III

TABLE A3-I

UNIT ALARM CONDITIONS AND AUTOMATIC ACTIONS

Shut-Down Sandbath		Shut-Down Autoclave		Shut-Down Everything	
Point	Trouble	Point	Trouble	Point	Trouble
PS 5,6	Hi-Lo H_2 Feed #1 Flow	PS 9,10	Hi-Lo H_2 Feed #3 Flow	PS 15,16	Hi-Lo PVT Pressure
PS 7,8	Hi-Lo H_2 Feed #2 Flow	PS 23,24	Hi-Lo Liq Blowcase #2 Level	GM3	Hi Preheater Temp
PS 21,22	Hi-Lo Liq Blowcase #1 Level	PS 3,4	Hi-Lo Liq Feed #2 Flow	PS 41	Lo Inst. Air Pressure
PS 1,2	Hi-Lo Liq Feed #1 Flow	PS 19,20	Hi-Lo Autoclave Pressure	PS 44	Lo Air Pressure
PS 11,12	Hi-Lo Recycle Flow	PS 25,26	Hi-Lo Depressurizer #2 Level	PS 43	Lo N_2 Pressure
PS 17,18	Hi-Lo SB Reactor Pressure	PS 35,36	Hi-Lo Liq Rec #2 Level	FS 2	No Cooling Water
PS 39,40	Hi-Lo SB Reactor ΔP	PS 37,28	Hi-Lo Autoclave Temp		
PS 27,28	Hi-Lo Depressurizer #1 Level	PS 45,46	Hi-Lc Additive Feed #2		
PS 31,32	Hi-Lo Liq Rec #1 Level				
GM1	Hi Sandbath #1 Temp				
GM2	Hi Sandbath #2 Temp				

Point	Action	Point	Action	Point	Action
SOL 13	Deenergizes, Vents ATO Control Valves in H_2 Feed #1 and 2, Liq Feed #1	SOL 15	Deenergizes, Vents ATO Control Valves in H_2 Feed #3, Liquid Feed #2 and Water Feed #2	All Actions for Sandbath and Autoclave Shutdown Plus:	
R_{P1}	Deenergizes to Turn Off Whitey Pump #1	R_{P5}	Deenergizes to Turn Off Whitey Pump #2	SOL 9	Deenergizes to Shut Off Compressors
SOL 13	Deenergizes, Vents ATC Control Valve to Drop Reactor Pressure	SOL 15	Deenergizes, Vents ATC Control Valve to Drop Autoclave Pressure	R_{P7}	Deenergizes to Turn Off Preheater Heaters
				R_{P8}	Deenergizes to Cut All Power But Only if PS 44 Activates
SOL 7	Deenergizes to Open Pneumatic Valve to Fill Reactor with Liquid Feed	SOL 8	Deenergizes to Open Pneumatic Valve to Fill Reactor with Liquid Feed		
R_{P2}	Deenergizes to Turn Off Zenith Recycle Pump	R_{P6}	Deenergizes to Turn Off Heater		
		SOL 15	Deenergizes to Vent ATC Additive Control Valve		
SOL 14	Deenergizes to Vent Pneumatic Cylinder and Lower Sandbath				
R_{P3}	Deenergizes to Turn Off Ruska Pump				
R_{P4}	Deenergizes to Turn Off Heaters				

APPENDIX IV

JFTOT APPARATUS DESCRIPTION AND JFTOT TESTING PROCEDURES

The Alcor, Inc. Jet Fuel Thermal Oxidation Tester was employed to access the tendency of the synthetic fuel blends to deposit decomposition products within a fuel system in what is referred to as the JFTOT test. This method for measuring the high temperature stability of aviation turbine fuels subjects the test fuel to temperatures and conditions similar to those occurring in aviation turbine engine fuel systems. The aerated fuel is pumped at a fixed volumetric flow rate through a heater, which simulates a hot fuel line section or a tube in a fuel heat exchanger. After passing over the heated surface, the fuel enters a precision stainless steel filter which represents the nozzle area, or small fuel passages in the hot sections of the engine fuel system, where fuel degradation products may become trapped. The essential data derived are (1) degree, distribution, and nature of surface deposits on an aluminum heater tube and (2) degree and rate of plugging of a 17-micron nominal porosity precision filter located just downstream of the heater tube.

The following description of the JFTOT apparatus and procedures is abstracted from the "Operating Manual for Alcor Jet Fuel Thermal Oxidation Tester", Report No. 70-158, by Alcor, Inc., San Antonio, Texas, October, 1970.

A4.1 The JFTOT Apparatus

A4.1.1 Fuel System

The Fuel System is shown in Figure A4-1. Test fuel contained in the reservoir is circulated through the test section by a Zenith constant displacement pump located downstream of the heater tube and filter to preclude contamination by pump wear particles. The pump is driven by a constant speed motor so as to have a displacement of 3.0 cc per minute.

From the reservoir outlet, the fuel flows through a 0.45-micron membrane type filter and thence to the lower (inlet) part of the heater tube section (see Figure A4-2). The heater tube is connected between two bus bars and is electrically insulated from the outer housing by means of a ceramic ferrule/O-ring seal combination. The fuel rises vertically in the annular space between the aluminum heater tube and its outer stainless steel housing. A low-voltage, high-current AC signal is passed through the heater tube and the tube's resistance heat loss is absorbed by the fuel resulting in an asymmetric tube surface temperature profile as shown in Figure A4-3. Exiting the heater tube section, the fuel passes through a test filter whose element is 17-micron micronic-rated Dutch weave 316 stainless steel cloth. A mercury manometer is connected to measure pressure drop across this filter - a direct measure of fouling rate and degree. Optionally, this Δ p versus

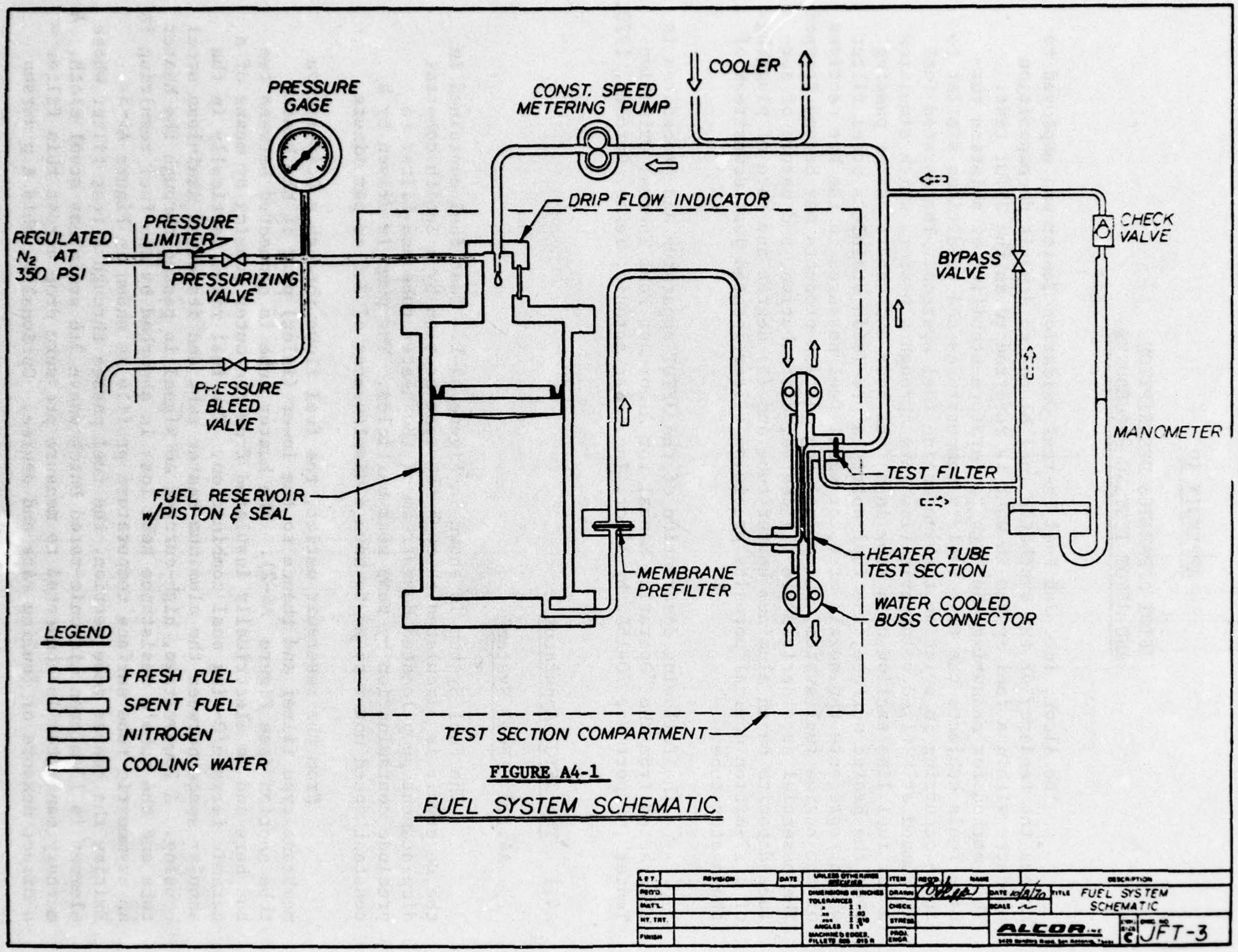


FIGURE A4-1

FUEL SYSTEM SCHEMATIC

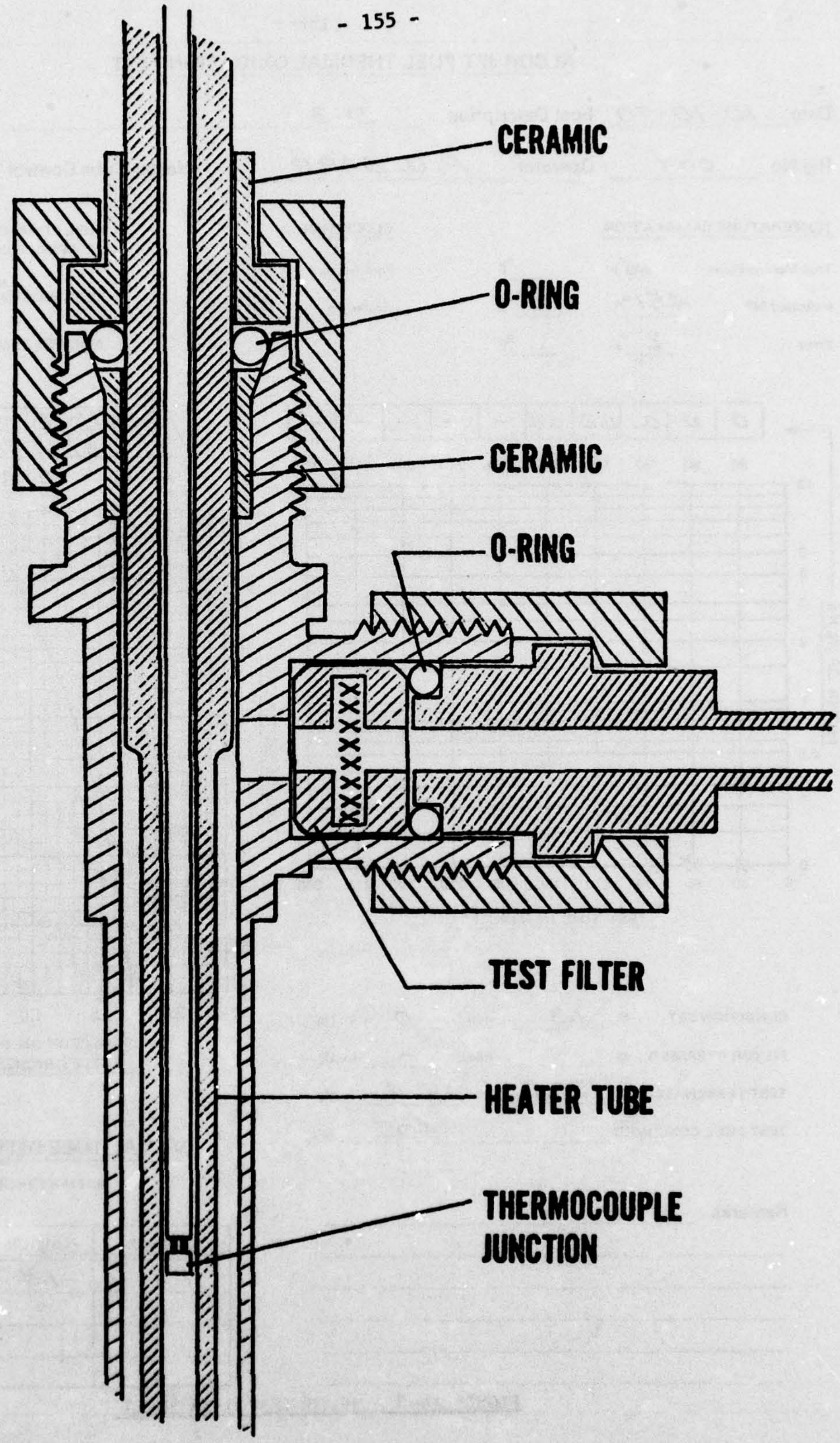


FIGURE A4-2 CROSS SECTION OF HEATER TUBE SECTION AT TEST FILTER

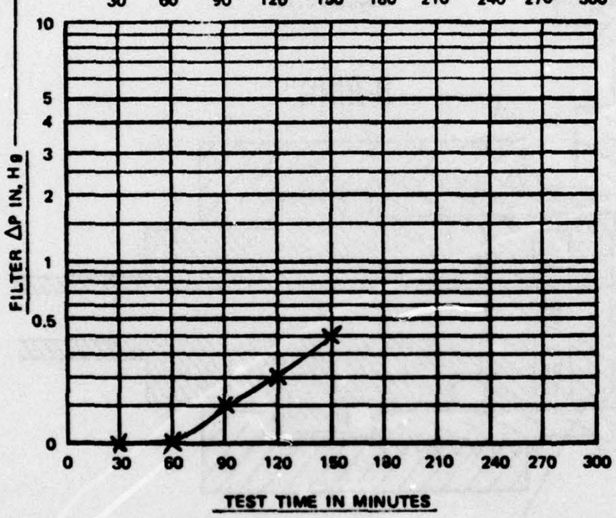
ALCOR JET FUEL THERMAL OXIDATION TEST

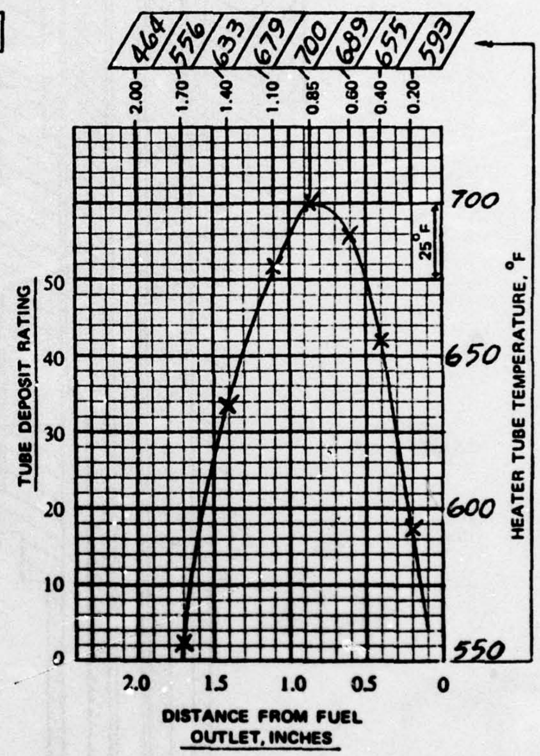
Date 10-10-70 Fuel Description D-3 Test No. 101

Rig No. 003 Operator F. U. BARR Heater Tube Control Temp. 700 °F

TEMPERATURE CALIBRATION			CLOCK TIME			
True Melting Point	449°F	___°F	Fuel Aerated	0820	FUEL TEMPERATURE AT AERATION	75 °F
Indicated MP	451°F	___°F	Heater On	0845	FUEL PRESSURE	350 PSI
Error	2 °F	___°F			AMBIENT TEMP.	75 °F

30	60	90	120	150	180	210	240	270	300
0	0	0.1	0.2	0.4	–	–	–	–	–





CONDITION SET ●	1.3	min.,	0	in.,Hg.
FILTER BYPASSED ●	–	min.,	–	in.,Hg.
TEST TERMINATED ●	150.0	min.,	0.4	in.,Hg.
TEST FUEL CONSUMED			450	ml.

Remarks ______________________

VISUAL TUBE DEPOSIT RATING

ASTM METHOD D1660

CODE NO.	POSITION, IN.	TEMP., °F
1	1.3	649
2		
3		
4		

FIGURE A4-3 IFTOT TEST DATA SHEET

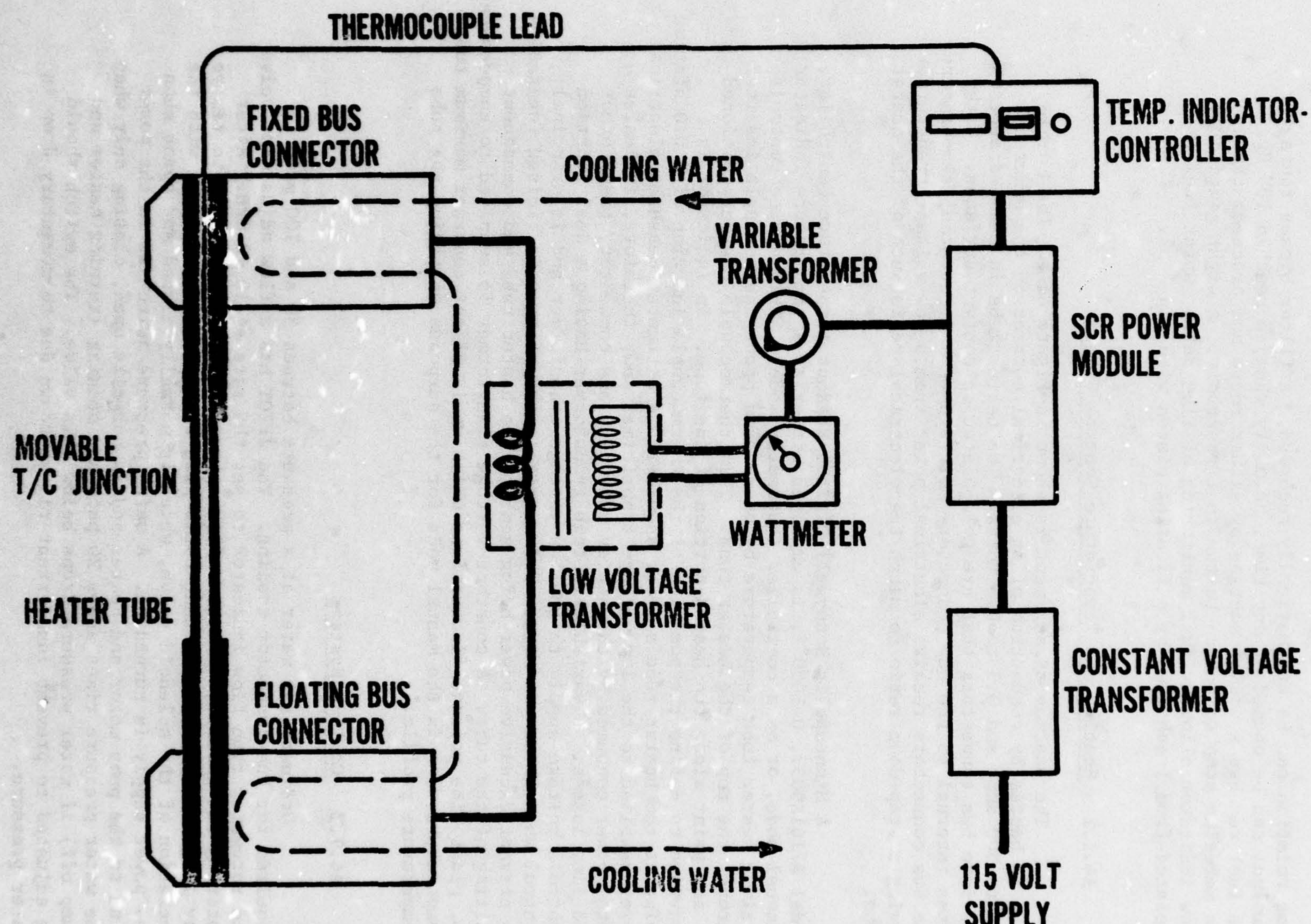


FIGURE A4-4 HEATER TUBE POWER AND TEMPERATURE CONTROL SCHEMATIC

time relation can be automatically recorded. A filter bypass route for the fuel can be opened at any time, normally when Δp reached 10" Hg. The fuel reaches a cooler section by either route and proceeds through the metering pump to return to the fuel reservoir. A sight gauge drip flow indicator allows visual monitoring of flow rate. Spent fuel is isolated from fresh fuel by a floating piston with lip seal.

A4.1.2 Heating and Temperature Control System

The heating arrangement is shown in Figure A4-4. The heater tube is heated by conduction of an electrical current on the order of 200 to 300 amps and 0.3 to 0.5 volts. The heater tube is clamped at each end into bus connectors that are gold-plated on contact surfaces. Water lines internal to the bus connectors maintain them at constant temperature. The bus connectors receive electrical power from a low voltage transformer having a step-down ratio to match the electrical resistance of the heater tube.

A Minneapolis Honeywell Digital Readout Temperature Controller, Model R7161S9057, 0-1000°F, is employed either as a temperature indicator (manual mode) or as a controller (automatic mode). This device controls maximum heater tube temperature by means of a probe thermocouple inserted through the top of the heater tube. This thermocouple can be positioned at any point along the heated portion of the tube. An indicator is provided to define the position of the thermocouple junction with 0.0 station being at the heater tube's upper shoulder. A wattmeter measures electrical power supplied to the low voltage transformer and, therefore, indicates total power consumed by the heater tube plus bus connector, transformer and line losses. A variable voltage transformer having a dual function controls voltage supply to the low voltage transformer and is principal control when in manual mode. This variable transformer is limited internally to prevent excessive power being sent to the heater tube and consequent melting of the tube. A constant voltage transformer is supplied to compensate for plant line voltage fluctuations which would affect constant maximum tube temperature when in the manual mode for the purposes of taking the tube temperature profile.

A4.1.3 Cooling Systems

Ordinary tap water at a pressure between 30 and 100 psig is required for bus connector cooling. The JFTOT has a flow adjustment valve and rotometer type flow indicator to set the rate at 10 $\pm$2 GPH. After entering the cabinet, the water flows through a filter adequate to remove any large solid particles that could plug the lines or interfere with the operation of the solenoid valve, which is normally closed and opens when the power supply is turned on. A water pressure switch is in the power line to the pump motor and heater and is normally open, closing only when the water pressure rises above 20 psig and opening (turning heater and pump off) if water pressure drops below this valve. The switch should be adjusted to prevent inadvertent rig shutdown due to momentary drop in water pressure.

The water next flows through a heat exchange section used to cool spent test fuel prior to the fuel's entering the pump. After this, the water passes through copper tubing internally silver soldered to the bus connectors, maintaining them at constant temperature and thus holding a constant tube temperature profile. The water lines are electrically insulated from the system by means of polyethylene tubing.

A4.1.4 Fuel System Pressurization

A standard nitrogen cylinder with regulator is used to pressurize the fuel system, preventing significant fuel evaporation at elevated temperatures in the heater tube section. Normally, tests are run at 350 psig but all system components have been tested to 1000 psig and tests can be run at pressures to 400 psig. For safety, an adjustable pressure limiter is provided in the nitrogen inlet line and is set at approximately 375 psig. Two nitrogen control needle valves marked "Pressurize" and "Bleed" are provided. Their function is evident from the schematic, Figure A4-I. A 0-400 psig Bourdon tube gauge is provided to show system pressure.

A.4.1.5 Manometry System

A standard single leg 12-inch mercury manometer with a rated working pressure to 500 psig is connected across the test filter to measure filter pressure drop as the filter fouls with fuel deposition and/or degradation products. A manual bypass valve permits the spent test fuel to flow around a plugged filter when it is desired to continue the test to obtain heater tube deposits for an extended test period. A float-type check valve in the low pressure leg of the manometer prevents mercury from "going over the top" during abnormally high differential pressure surges and contaminating the fuel system.

Automatic recording of Δp vs. time can be obtained on a 10-channel event recorder which has dual speed capability of 60 and 360 mm per hour. Normal speed is 60 mm per hour. Reed type switches at stations 0.1, 0.3, 0.5, 1.0, 2.0, 3.0, 5.0 and 10.0" Hg. respectively are mounted adjacent to the manometer tube and are activated by a small Teflon-enclosed magnet floating on top of the mercury column. As Δp increases, the magnet activates each switch and the resulting signal records the event on the appropriate channel of the vent recorder. A Δp warning system sounds a horn when the Δp reaches 5.0"Hg. to alert the operator of impending rig shutdown at 10" Hg.

A4.1.6 Thermocouple Calibration System

The AutoCal calibration system provides for an easy and reliable check of the calibration of the entire temperature indication system by utilizing the freezing point of 99.99% pure tin at 449°F as the primary standard. Other pure metals can be used. The AutoCal consists of a special heater tube device which has at its middle section a small well containing pure tin into which the thermocouple is immersed. The test thermocouple is introduced into a container of tin, an energy pulse is applied to melt the tin and the cool-down temperature-time characteristic

is observed by the operator, who notes the temperature indication at which the deviation needle pauses. Any difference between this reading and 449°F must be taken into account when setting maximum heater tube control temperature and when plotting heater tube temperature profiles.

A4.1.7 Fuel Aeration System

Provision is made to air saturate the test fuel charge in the reservoir prior to test. A rotometer flow control and automatic timer-cutoff are set to flow dry, filtered air at 1500 cc/minute for 6 minutes. The 9.0 liters thus passed through the 1.0 liter fuel charge insures at least 97% of air saturation at 75°F and 1 atmosphere, providing a common comparative basis for all fuels.

A4.1.8 Elapsed Time Test Measurement

There are two indications of elapsed test time on the JFTOT: a digital readout indicator (to nearest 0.1 minute) and a timer-cutoff (to nearest 3 minutes) which can be set to cut off at desired time up to 5.0 hours. The automatic Δp recorder provides yet a third measure of elapsed test time.

A.4.2 Tube Deposit Rater (Alcor Mark 8A)

This instrument has been developed to provide a quantitative means for heater tube deposit evaluation. The JFTOT heater tube is placed in a holder within the cabinet and light is reflected from the tube's surface to an ultrasensitive photocell with amplifying circuit to obtain a Tube Deposit Rating of from 0 (clean tube) to 50 (heavy deposit) at each selected tube station. The maximum spot ratings obtained at each station are plotted against tube length.

An extension of the rating procedure is possible with the recent versions of the tube rater. In this case, the tube to be rated is spun, resulting in an average, or so-called constant temperature area (CTA), rating around the tube circumference. The maximum spun rating observed along the tube is the rating reported for the heater tube control temperature at which the tube was tested. These maxima are plotted against temperature; and the temperature at which a spun tube deposit rating of 13 obtains is reported as the "breakpoint temperature". A fuel which has a breakpoint temperature above 500°F is considered acceptable in the JFTOT rating.

A.4.3 General Test Procedure

The complete test section is disassembled and cleaned after each test with certain key items (heater tube, test filter, prefilter element, and O-rings) replaced. After cleaning and drying, the heater tube section is reassembled and installed in the cabinet and a fresh charge of test fuel is filtered into the reservoir and aerated. The reservoir is then installed, the fuel system is pressurized, and flow is started through the heater tube section as temperature is automatically

elevated to the pre-selected control temperature. When this temperature is reached (normally within 1-3 minutes), the filter bypass valve is closed and the initial manometer setting is taken. From this point the test proceeds automatically with the heater tube temperature, fuel flow rate, and pressure held constant. Filter pressure drop values may be taken manually or recorded automatically. At some time during the test, the temperature controller mode is switched from "automatic" to "manual" and a heater tube temperature profile is taken by means of the probe thermocouple. Following this, the controller is returned to "automatic" mode and the test continues for the preset duration. If filter Δp reached 5.0"Hg., an alarm (if activated) will sound, alerting the operator who can (if he wishes) then open the bypass valve prior to the magnet's tripping the automatic rig cutoff at the 10.0"Hg. station. This will allow the test to continue for the preset duration - usually for the purpose of comparative heater tube deposit test sequences.

At the end of each test, the rig is depressurized and the heater tube is removed, rinsed, dried, and rated (either visually and/or by means of the ALCOR Mark 8 TDR). Pass-fail criteria with regard to maximum allowable heater tube deposit level and filter Δp are then considered (see Section A4.2 above).

APPENDIX V

CRUDE ASSAY - PARAHO SHALE OIL

CRUDE:	PARAHO SHALE OIL
LOCATION:	Rifle, Colorado
REPRESENTATIVE OF:	Oil extracted from shale in the semiworks retort and pilot plant operated by Paraho Development Corporation at federally-owned Anvil Points oil shale facilities.

FILE NO.:	SL. 33C-FP. 75
REPORT DATE:	7-10-75
REPORT BY:	Garry N. Williams

EXXON RESEARCH & ENGINEERING CO.
ENGINEERING INFORMATION CENTER
FLORHAM PARK, N.J.

DATE RECEIVED:	1-7-75
DATE DISTILLED:	2-3-75
LAB ASSAY NO.:	2049
COST CENTER:	2524-634

ASSAY RUN BY:

EXXON COMPANY, U.S.A.
REFININGI DEPARTMENT
REFINERY LABORATORY
BAYTOWN, TEXAS

SPONSORED BY: EXXON COMPANY, U.S.A. – SUPPLY DEPARTMENT

TABLE 1

CRUDE	
PARAHO SHALE OIL	SL. 33C-FP. 75

WHOLE CRUDE DATA

GRAVITY		°API	19.3
SPECIFIC GRAVITY		60/60	0.9383
SULFUR		WT. %	0.71
MERCAPTAN SULFUR		WT. PPM	56
POUR POINT		°F	85
NITROGEN		WT. %	2.00
WATER AND SEDIMENT		VOL. %	0.9
SALT CONTENT, NaCl		PTB	0.9
REID VAPOR PRESSURE		PSI	
H_2S (DISSOLVED)		WT. PPM	0
NEUT. NO. (D664)		mg KOH/gm	1.8
VISCOSITIES	KINEMATIC	122°F, cSt	42.6
		100°F, cSt	78.5
		80°F, cSt	
		60°F, cSt	
		40°F, cSt	
	SAYBOLT UNIVERSAL	122°F, SEC	199
		100°F, SEC	364
		80°F, SEC	
		60°F, SEC	
		40°F, SEC	

LIGHT HYDROCARBONS

% ON CRUDE	WEIGHT	VOLUME
ETHANE AND LIGHTER		
PROPANE		
ISO BUTANE		
NORMAL BUTANE		
ISO PENTANE		
NORMAL PENTANE		

TABLE 2

PARAHO SHALE OIL DATA INPUT AND CALCULATIONS 19.3 DEG API SL. 33C- FP. 75

TEMPERATURE DEG F	DEG C	NORM. VOL. PCT ON CRUDE	CUM	MID	GRAVITY DEG API	SPECIFIC	SUM OF SPEC GRAV X VOL PCT	RI AT 67 DEG C	DEG F AN. PT.	SUM OF VOL PCT X AN. PT.	VOL % AROM.	SUM OF VOL PCT X AROM.	VOL % NAPTH.
302	150.0	0.0	0.0	0.0	0.0	1.0760	0.0				0.0	0.0	0.0
320	160.0	0.35	0.35	0.18	43.8	0.8072	0.28252	1.4285	69	24.1	0.0	0.0	0.0
347	175.0	0.25	0.60	0.48	41.8	0.8165	0.48664	1.4333	69	41.4	0.0	0.0	0.0
374	190.0	0.40	1.00	0.80	39.8	0.8260	0.81706	1.4365	69	69.0	0.0	0.0	0.0
401	205.0	0.50	1.50	1.25	38.4	0.8328	1.23348	1.4390	69	103.5	0.0	0.0	0.0
428	220.0	0.60	2.10	1.80	37.2	0.8388	1.73674	1.4413	69	144.9	0.0	0.0	0.0
455	235.0	1.50	3.60	2.85	36.9	0.8403	2.99713	1.4440	69	248.4	0.0	0.0	0.0
482	250.0	1.80	5.40	4.50	33.8	0.8560	4.53796	1.4503	69	372.6	0.0	0.0	0.0
509	265.0	2.10	7.50	6.45	32.0	0.8654	6.35539	1.4595	72	523.8	0.0	0.0	0.0
536	280.0	2.60	10.10	8.80	30.0	0.8762	8.63341	1.4665	81	734.4	0.0	0.0	0.0
563	295.0	3.00	13.10	11.60	28.2	0.8860	11.29152	1.4714	95	1019.4			
590	310.0	3.50	16.60	14.85	28.7	0.8833	14.38297	1.4745	100	1369.4			
617	325.0	3.80	20.40	18.50	27.6	0.8894	17.76259	1.4754	97	1734.0			
653	343.3	4.50	24.90	22.65	24.8	0.9053	21.83647	1.4841	91	2147.5			
671	355.0	2.80	27.70	26.30	22.6	0.9182	24.40753	1.4927	91	2402.3			
698	370.0	4.10	31.80	29.75	21.8	0.9230	28.19194	1.4952	94	2787.7			
725	385.0	4.20	36.00	33.90	21.4	0.9254	32.07878	1.4975	96	3190.9			
752	400.0	4.50	40.50	38.25	20.7	0.9297	36.26242	1.4999	100	3640.9			
779	415.0	5.00	45.50	43.00	20.3	0.9321	40.92316	1.5028	105	4165.9			
806	430.0	4.70	50.20	47.85	19.6	0.9365	45.32454	1.5060	111	4687.6			
833	445.0	4.70	54.90	52.55	19.1	0.9396	49.74052	1.5092	115	5228.1			
851	455.0	2.90	57.80	56.35	18.5	0.9433	52.47620	1.5121	116	5564.5			
887	475.0	6.60	64.40	61.10	17.5	0.9497	53.74396	1.5156	115	6323.5			
914	490.0	4.60	69.00	66.70	16.6	0.9554	63.13896	1.5201	108	6820.3			
950	510.0	6.10	75.10	72.05	15.5	0.9626	69.01073	1.5247	94	7393.7			
995	535.0	7.30	82.40	78.75	14.4	0.9698	76.09056	1.5311	94	8079.9			
1022	550.0	4.30	86.70	84.55	14.8	0.9672	80.24948	1.5376	116	8578.7			
1049	565.0	4.30	91.00	88.85	13.0	0.9792	84.46021	1.5435	126	9120.5			
1049+	565.0+	9.00	100.00	95.50	5.3	1.0344	93.76941						

TABLE 3

PARAHO SHALE OIL DATA INPUT AND CALCULATIONS 19.3 DEG API SL. 33C- PP. 75

TEMPERATURE DEG F	TEMPERATURE DEG C	CALC WT PCT ON CRUDE	NORM WT PCT ON CRUDE	NORM WT PCT CUM	NORM WT PCT MID	SUM WT PCT SULFUR X NORM WT PCT	WT PCT SULFUR	WT PCT CON CARBON	SUM WT PCT CON CARBON X NORM WT PCT	WT PCT NITROGEN	SUM WT PCT NITROGEN X NORM WT PCT
302	150.0	0.0	0.0	0.0	0.0	0.0	0.0				
320	160.0	0.31	0.30	0.30	0.15	0.353	1.1700				
347	175.0	0.22	0.22	0.52	0.41	0.575	1.0200				
374	190.0	0.35	0.35	0.87	0.70	0.849	0.7800				
401	205.0	0.44	0.44	1.32	1.09	1.187	0.7600				
428	220.0	0.54	0.54	1.85	1.58	1.584	0.7400				
455	235.0	1.34	1.34	3.20	2.52	2.337	0.5600				
482	250.0	1.64	1.64	4.84	4.02	3.388	0.6400				
509	265.0	1.94	1.94	6.78	5.81	4.784	0.7200				
536	280.0	2.43	2.43	9.21	7.99	6.727	0.8000				
563	295.0	2.83	2.83	12.04	10.62	9.052	0.8200			1.6200	12.1099
590	310.0	3.29	3.30	15.34	13.69	11.261	0.6700			1.8200	18.1102
617	325.0	3.60	3.60	18.94	17.14	13.459	0.6100			1.9300	25.2455
650	343.3	4.34	4.34	23.29	21.12	16.457	0.6900			2.0800	34.2832
671	355.0	2.74	2.74	26.03	24.66	18.568	0.7700	0.01	0.2274	2.1000	40.0412
698	370.0	4.03	4.04	30.07	28.05	21.636	0.7600	0.01	0.0673	2.0500	48.3147
725	385.0	4.14	4.15	34.21	32.14	24.454	0.6800	0.02	0.1507	1.9200	56.2733
752	400.0	4.46	4.46	38.67	36.44	27.265	0.6300	0.04	0.3291	1.7300	53.9919
779	415.0	4.97	4.97	43.64	41.16	30.247	0.6000	0.08	0.7268	1.6300	72.0937
806	430.0	4.67	4.69	48.34	45.99	32.923	0.5700	0.14	1.3839	1.6000	79.6038
833	445.0	4.71	4.71	53.05	50.69	35.513	0.5500	0.24	2.5142	1.6200	87.2331
851	455.0	2.92	2.92	55.96	54.50	37.059	0.5300	0.38	3.6228	1.7000	92.1927
887	475.0	6.68	6.58	62.65	59.31	40.736	0.5500	0.66	8.0344	1.9000	
914	490.0	4.68	4.69	67.33	64.99	43.454	0.5800	1.24	13.8463	2.1400	
950	510.0	6.26	6.28	73.60	70.47	47.399	0.6300	2.10	26.9964	2.3000	
995	535.0	7.55	7.55	81.15	77.37	51.854	0.5900	3.70	54.9323	2.4000	
1022	550.0	4.43	4.44	85.59	83.36	54.293	0.5500	5.30	78.4392	2.3200	
1049	565.0	4.49	4.49	90.07	87.83	56.583	0.5100	6.54	*******	2.2100	
1049+	565.0+	9.92	9.93	100.00	95.04	61.349	0.4800			3.0600	
		99.93									

PARAHO SHALE OIL CALCULATED BLENDS 19.3 DEG API SL. 33C- FP. 75 TABLE 4

TEMP. RANGE F		VOLUME % INIT	VOLUME % FINAL	VOLUME YIELD	MID VOLUME	GRAVITY DEG API	GRAVITY SPECIFIC	NORM WT PCT	SULFUR WT PCT	RI AT 67 DEG C	CON CARBON	WT PCT NITROGEN	ANILINE PT	VOL PCT AROMATICS
302	374	0.0	1.00	1.00	0.50	41.68	0.8171	0.87	0.9748	1.4329			0	0.0
302	401	0.0	1.50	1.50	0.75	40.57	0.8223	1.32	0.9023	1.4349			69	0.0
302	455	0.0	3.60	3.60	1.80	38.46	0.8325	3.20	0.7311	1.4398			69	0.0
302	509	0.0	7.50	7.50	3.75	35.48	0.8474	6.78	0.7058	1.4478			70	0.0
302	536	0.0	10.10	10.10	5.05	34.06	0.8548	9.21	0.7307	1.4526			73	0.0
302	690	0.0	31.80	31.80	15.90	28.11	0.8865	30.07	0.7196	1.4730			89	0.0
323	650	0.35	24.90	24.55	12.62	29.67	0.8780	22.99	0.7006	1.4677			86	0.0
347	690	0.60	31.80	31.20	16.20	27.85	0.8880	29.55	0.7128	1.4738			88	0.0
374	482	1.00	5.40	4.40	3.20	35.82	0.8457	3.97	0.6399	1.4456			69	0.0
374	536	1.00	10.10	9.10	5.55	33.24	0.8589	8.34	0.7052	1.4548			73	0.0
401	509	1.50	7.50	6.00	4.50	34.26	0.8537	5.46	0.6585	1.4510			70	0.0
401	650	1.50	24.90	23.40	13.20	29.21	0.8805	21.97	0.6950	1.4692			87	0.0
428	536	2.10	10.10	8.30	6.10	32.64	0.8621	7.35	0.6993	1.4568			74	0.0
509	590	7.50	16.60	9.10	12.05	23.90	0.8822	8.56	0.7566	1.4712		1.6431	93	0.0
536	650	10.10	24.90	14.80	17.50	27.11	0.8921	14.08	0.6910	1.4770		1.9009	95	0.0
590	650	16.60	24.90	8.30	20.75	26.07	0.8980	7.95	0.6537	1.4801		2.0347	94	0.0
590	690	16.60	31.80	15.20	24.20	24.25	0.9085	14.73	0.7045	1.4865		2.0510	93	0.0
650	752	24.90	40.50	15.60	32.70	21.52	0.9247	15.38	0.7025	1.4967	0.02	1.9311	96	0.0
650	851	24.90	57.80	32.90	41.35	20.44	0.9313	32.68	0.6305	1.5021	0.11	1.7723	104	0.0
690	1049	24.90	91.00	66.10	57.95	17.85	0.9474	66.78	0.6008	1.5150	1.61	1.9971	105	0.0
752	851	40.50	57.80	17.30	49.15	19.48	0.9372	17.29	0.5664	1.5070	0.19	1.6309	111	0.0
779	995	45.50	82.40	36.90	63.95	16.97	0.9530	37.50	0.5761	1.5184	1.45	2.0092	106	0.0
851	950	57.80	75.10	17.30	66.45	16.55	0.9558	17.63	0.5864	1.5207	1.33	2.1958	106	0.0
851	1049	57.80	91.00	33.20	74.40	15.38	0.9634	34.11	0.5724	1.5278	3.05	2.2125	107	0.0
950	1049	75.10	91.00	15.90	83.05	14.13	0.9717	16.48	0.5574	1.5362	4.90	2.3267	109	0.0
995	1049	82.40	91.00	8.60	86.70	13.89	0.9732	8.93	0.5299	1.5405	5.92	2.2647	121	0.0

RESIDUE

DEG F TEMP	VLD% VOLUME	GRAVITY DEG API	GRAVITY SPECIFIC	YLD WT PCT	WT% SULFUR	WT% CON CARBON	WT% NITROGEN
1049+	9.00	5.3	1.0344	9.93	0.48	24.70	3.06
950+	24.90	10.8	0.9943	26.40	0.53	12.35	2.60
851+	42.20	13.1	0.9785	44.04	0.55	7.93	2.40
752+	59.50	14.9	0.9665	61.33	0.56	5.75	2.19
690+	68.20	15.7	0.9615	69.93	0.57	5.05	2.14
650+	75.10	16.2	0.9578	76.71	0.59	4.60	2.13
563+	86.90	17.6	0.9491	87.96	0.59	4.01	2.11
428+	97.40	19.0	0.9401	98.15	0.61	3.60	2.02

INITIAL F	401	509	590	650	752	851	950	428	536	650	851
FINAL F	509	590	650	752	851	950	1049	536	650	851	1049
AR =	9.21	12.99	13.35	15.96	17.11	13.94	23.38	10.19	13.50	16.79	21.25
NR =	36.80	39.29	40.24	45.12	45.27	49.36	54.47	37.40	40.18	45.40	51.61

TABLE 5

CRUDE	
PARAHO SHALE OIL	SL. 33C-FP. 75

GASOLINES & NAPHTHAS

15/5 CUT POINT	°F VT	68/158	68/212	158/212	212/302	248/374	302/374
15/5 CUT POINT	C VT	20/70	20/100	70/100	100/150	120/190	150/190
YIELD CUT RANGE	VOL. %						0.0-1.0
YIELD ON CRUDE	VOL. %						1.0
MID-POINT	VOL. %						0.5
GRAVITY	°API						41.7
SPECIFIC GRAVITY	60/60						0.8170
TOTAL SULFUR	WT. %						0.98
MERCAPTAN SULFUR	WT. PPM						153
REID VAPOR PRESSURE	PSI						
RESEARCH OCTANE NUMBER							
CLEAR							
+ 1.5 ml TEL/USG							
+ 3.0 ml TEL/USG							
MOTOR OCTANE NUMBER							
CLEAR							
+ 1.5 ml TEL/USG							
+ 3.0 ml TEL/USG							
VOL. % D + L @ 70°C/158°F							
@ 100°C/212°F							
FBP °F							
ANILINE POINT, °F							
		GC		GC	GC HC		HC
PARAFFINS	VOL. %						
NAPHTHENES	VOL. %						
AROMATICS	VOL. %						

TABLE 6

CRUDE	PARAHO SHALE OIL	SL. 33C-FP. 75

KEROSENE & TURBO FUELS

15/5 CUT POINT	°F VT	302-401	302-455	302-509	374-482	374-536
15/5 CUT POINT	°C VT	150-205	150-235	150-265	190-250	190-280
YIELD CUT RANGE	VOL. %	0.0-1.5	0.0-3.6	0.0-7.5	1.0-5.4	1.0-10.1
YIELD ON CRUDE	VOL. %	1.5	3.6	7.5	4.4	9.1
MID-POINT	VOL. %	0.8	1.8	3.8	3.2	5.6
GRAVITY	°API	40.6	38.5	35.5	35.8	33.2
SPECIFIC GRAVITY	60/60	0.8222	0.8324	0.8473	0.8458	0.8591
TOTAL SULFUR	WT. %	0.90	0.73	0.71	0.64	0.71
MERCAPTAN SULFUR	WT. PPM	174	180	174	182	175
SMOKE POINT	MM	17	17	15	16	14
LUM. NO.		37	35	31	32	27
FREEZING POINT	°F	too dark				
CLOUD POINT	°F	too dark				
POUR POINT	°F	<-70	-70	-50	-55	-40
ANILINE POINT	°F	69	69	70	69	73
DIESEL INDEX		28	26	25	25	24
COLOR	SAYBOLT					
REFRACTIVE INDEX @ 67°C		1.4349	1.4398	1.4478	1.4456	1.4548
AROMATICS, FIA	VOL. %					
VISCOSITIES:						
KINEMATIC @ -30°F	cSt	6.06	11.6	25.1	24.4	48.4
@ 100°F	cSt	1.12	1.49	1.96	1.93	2.45
@ 210°F	cSt	0.58	0.70	0.85	0.84	0.98

TABLE 7

CRUDE	
PARAHO SHALE OIL	SL. 33C-FP.75

MIDDLE DISTILLATES

15-5 CUT POINT	F VT	401-509	509-590	590-650	590-698	320-650	401-650	302-698	
15-5 CUT POINT	C VT	205-265	265-310	310-343	310-370	160-343	205-343	150-370	
YIELD CUT RANGE	VOL. %	1.5-7.5	7.5-16.6	16.6-24.9	16.6-31.8	0.3-24.9	1.5-24.9	0.0-31.8	
YIELD ON CRUDE	VOL. %	6.0	9.1	8.3	15.2	24.6	23.4	31.8	
MID-POINT	VOL. %	4.5	12.0	20.8	24.2	12.6	13.2	15.9	
GRAVITY	API	34.3	28.9	26.1	24.2	29.7	29.2	28.1	
SPECIFIC GRAVITY	60/60	0.8534	0.8822	0.8978	0.9088	0.8778	0.8805	0.8866	
TOTAL SULFUR	WT. %	0.66	0.76	0.65	0.70	0.70	0.70	0.72	
ANILINE POINT	F	70	93	94	93	86	87	88	
DIESEL INDEX		24	27	24	23	26	25	25	
CETANE INDEX		38	42	46					
CLOUD POINT	F	Too Dark							
POUR POINT	F	-50	-10	30	40	0	0	15	
REFRACTIVE INDEX @ 67°C		1.4510	1.4712	1.4801	1.4865	1.4677	1.4692	1.4730	
NEUT. NO. (D-974)	mg KOH/gm	3.7	3.5	3.0					
VISCOSITIES:									
KINEMATIC @ 100°F	cSt	2.33	4.41	9.31	12.3	4.25	4.59	5.40	
@ 150°F	cSt	1.44	2.38	4.09	5.03	2.33	2.43	2.74	
@ 175°F	cSt								
@ 210°F	cSt	0.93	1.41	2.14	2.52	1.37	1.44	1.58	
A.R.		9.2	13.0	13.4					
N.R.		36.8	39.3	40.2					
NITROGEN	WT. %	1.01	1.64	2.03	2.05				

TABLE 8

CRUDE	
PARAHO SHALE OIL	SL. 33C-PP. 75

GAS OILS

15/5 CUT POINT	°F VT	650-752	752-851	851-950	950-1049	650-851	650-1049	851-1049	995-1049
15.5 CUT POINT	°C VT	343-400	400-455	455-510	510-565	343-455	343-565	455-565	535-565
YIELD CUT RANGE	VOL. %	24.9-40.5	40.5-57.8	57.8-75.1	75.1-91.0	24.9-57.8	24.9-91.0	57.8-91.0	82.4-91.0
YIELD ON CRUDE	VOL. %	15.6	17.3	17.3	15.9	32.9	66.1	33.2	8.6
MID-POINT	VOL. %	32.7	49.2	66.5	83.0	41.4	58.0	74.4	86.7
GRAVITY	°API	21.5	19.5	16.6	14.1	20.4	17.8	15.4	13.9
SPECIFIC GRAVITY	60/60	0.9248	0.9371	0.9554	0.9718	0.9315	0.9478	0.9632	0.9732
TOTAL SULFUR	WT. %	0.70	0.57	0.59	0.56	0.63	0.60	0.57	0.53
ANILINE POINT	°F	96	111	106	109	104	105	107	121
CON CARBON	WT. %	0.02	0.19	1.33	4.90	0.11	1.61	3.05	5.92
POUR POINT	°F	65	90	105	110	75		110	110
REFRACTIVE INDEX ; 67°C		1.4967	1.5070	1.5200	1.5362	1.5021	1.5150	1.5278	1.5405
NEUT. NO.	mg KOH/gm					0.32			
NITROGEN	WT. %	1.93	1.63	2.10	2.33	1.77	2.00	2.21	2.26
VISCOSITIES									
KINEMATIC : 100°F	cSt	25.8	(119)						
@ 150°F	cSt	8.90	26.8	89.1	380	15.4	43.5	169	532
; 175°F	cSt								
; 210°F	cSt	3.80	8.32	20.4	58.9	5.58	12.2	32.7	78.0
BASIC NITROGEN	WT. %					1.03		1.27	
OXYGEN	WT. %							0.99	
METALS									
VANADIUM	WT. PPM							<0.1	
NICKEL	WT. PPM							2.9	
IRON	WT. PPM							4.2	
A.R.		16.0	17.1	18.9	23.4				
N.R.		45.1	45.3	49.4	54.7				

TABLE 9

CRUDE	
PARAHO SHALE OIL	SL. 33C-FP. 75

LUBE DISTILLATES

		WAXY LUBE	DEWAXED LUBE
15/5 CUT POINT	°F VT	779-995	
15/5 CUT POINT	°C VT	415-535	
YIELD CUT RANGE	VOL. %	45.6-81.6	
YIELD ON CRUDE	VOL. %	36.0	
MID-POINT	VOL. %	63.6	
GRAVITY	°API	17.0	
SPECIFIC GRAVITY	60/60	0.9529	
TOTAL SULFUR	WT. %	0.58	
CON CARBON	WT. %	1.36	
ANILINE POINT	°F	103	
REFRACTIVE INDEX @ 67°C		1.5184	
NEUT. NO. (D-974)	mg KOH/gm	0.51	
NITROGEN	WT. %	2.01	
POUR POINT	°F	100	
WAX CONTENT	WT. %		
WAX MELTING POINT	°F		
VISCOSITY INDEX		<0	
VISCOSITIES:			
KINEMATIC @ 100°F	cSt	(433)	
@ 150°F	cSt	69.1	
@ 175°F	cSt		
@ 210°F	cSt	17.0	
SAYBOLT UNIVERSAL @ 100°F	SEC	2006	
@ 210°F	SEC	86.0	

PHENOL TREATING SUSCEPTIBILITY*

PHENOL TREATING CHARACTERISTICS OF DEWAXED LUBE CUT

PHENOL/OIL RATIO

Treat	VI
RAW STOCK	
1/1	
2/1	
3/1	
VISCOSITY GRAVITY CONSTANT	

*From Established Correlations

Yields on this table are those as cut from still and the inspections are raw data, not correlated

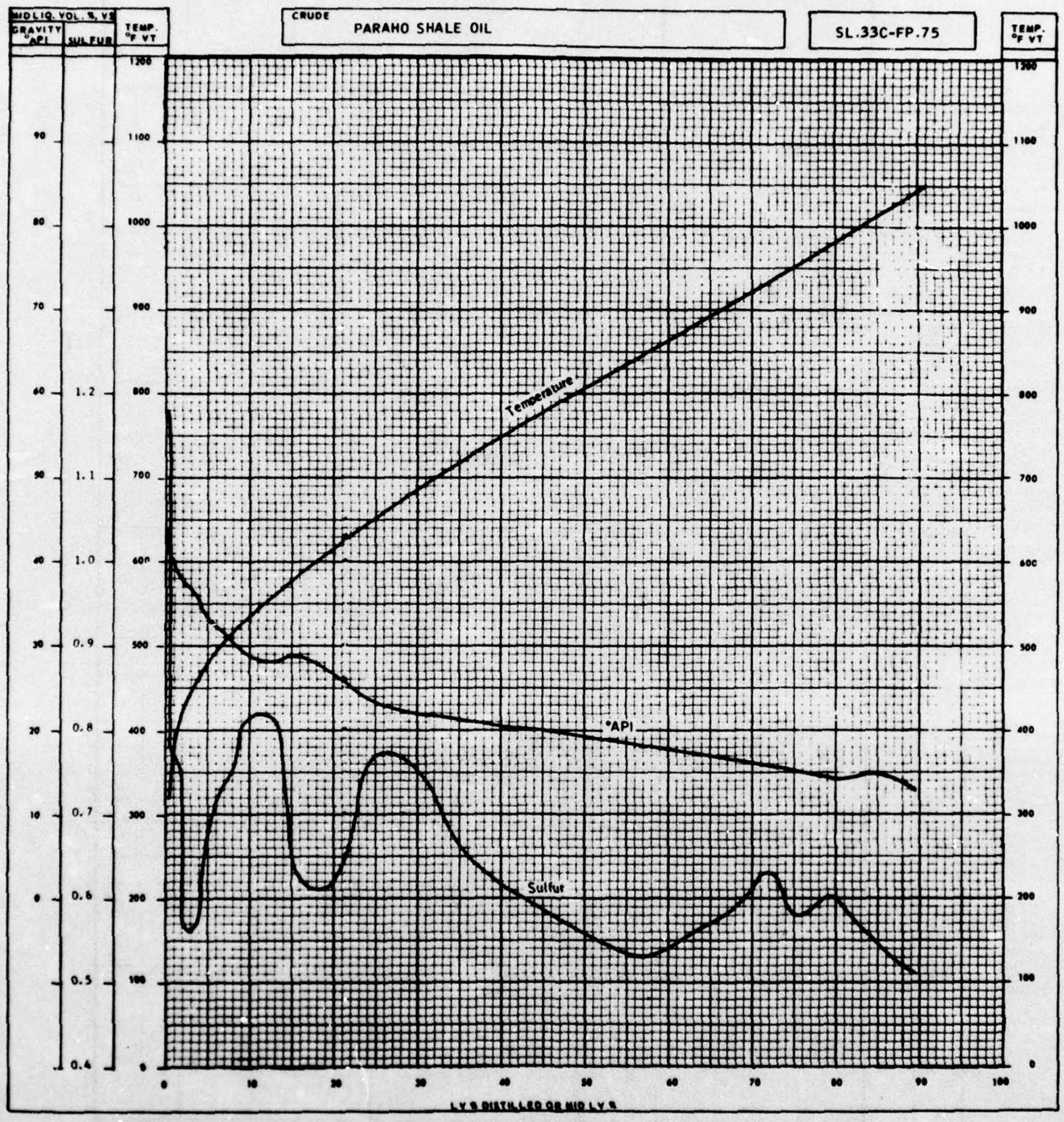
TABLE 10

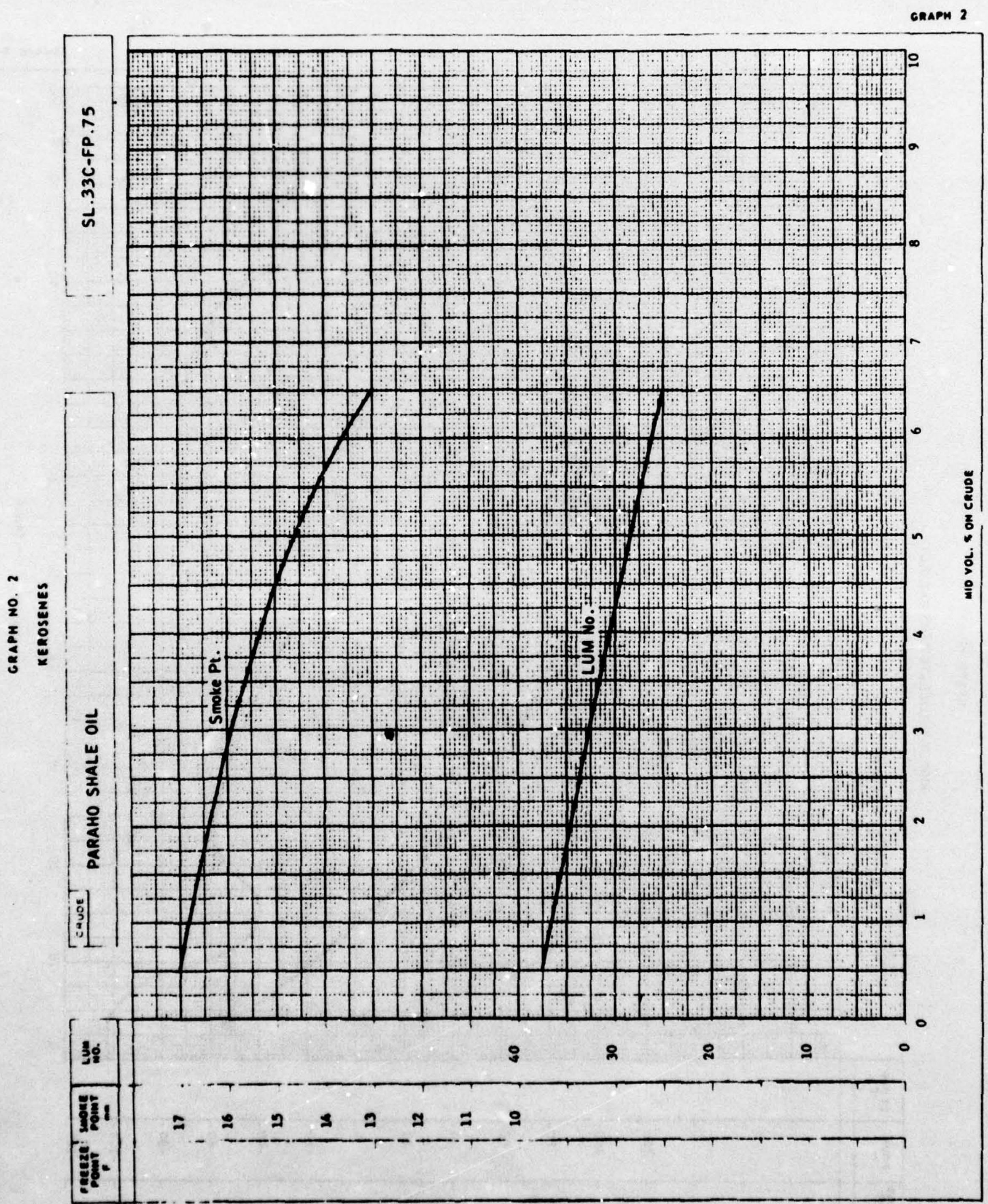
CRUDE: PARAMO SHALE OIL — SL33C-FP.75

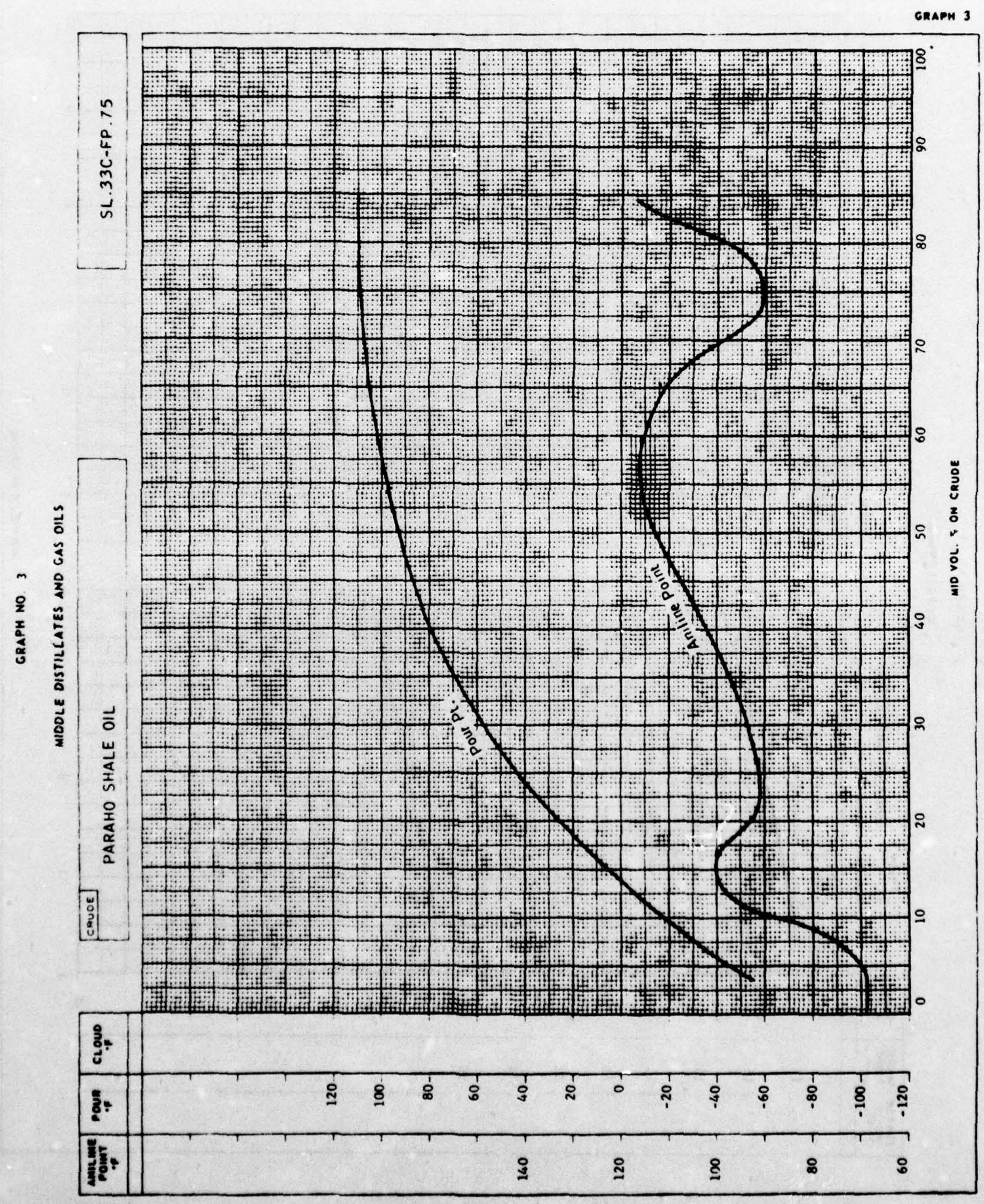
RESIDUA

15.5 CUT POINT	°F VT	650+	698+	752+	851+	950+	1049+		
15.5 CUT POINT	°C FT	343+	370+	400+	455+	510+	565+		
YIELD ON CRUDE	VOL. %	75.1	68.2	59.5	42.2	24.9	9.0		
GRAVITY	°API	16.2	15.7	14.9	13.1	10.8	5.3		
SPECIFIC GRAVITY	60/60	0.9580	0.9613	0.9665	0.9786	0.9944	1.0344		
TOTAL SULFUR	WT. %	0.59	0.57	0.56	0.55	0.53	0.48		
CON CARBON	WT. %	4.6	5.0	5.8	7.9	12.4	24.7		
NITROGEN	WT. %	2.13	2.14	2.19	2.40	2.60	3.06		
NEUT NO. (D-664)	mg KOH/gm	0.55							
POUR POINT	°F	95	105	115					
VISCOSITIES									
KINEMATIC @ 100°F	cSt	570	900	(1600)					
@ 122°F	cSt	229	335	569					
@ 150°F	cSt	89.5	124	184	485				
@ 175°F	cSt	45.0	59.0	84.6	208	838			
@ 210°F	cSt	21.2	26.4	35.7	76.1	243	9899		
FUROL @ 275°F	SEC						350		
@ 300°F	SEC								
UNIVERSAL @ 210°F	SEC	103.6	126.4	168.3	355	1133			
REDWOOD I @ 100°F	SEC	2324	3669						
ABSOLUTE VISC. @ 140°F	POISES								
METALS:									
VANADIUM	WT. PPM	0.75			1.3		5.8		
NICKEL	WT. PPM	5.9			10.3		35.7		
IRON	WT. PPM	83			145		629		
[illegible]	WT. %								
[illegible]	WT. %								
OXYGEN	WT. %								

GRAPH NO. 1

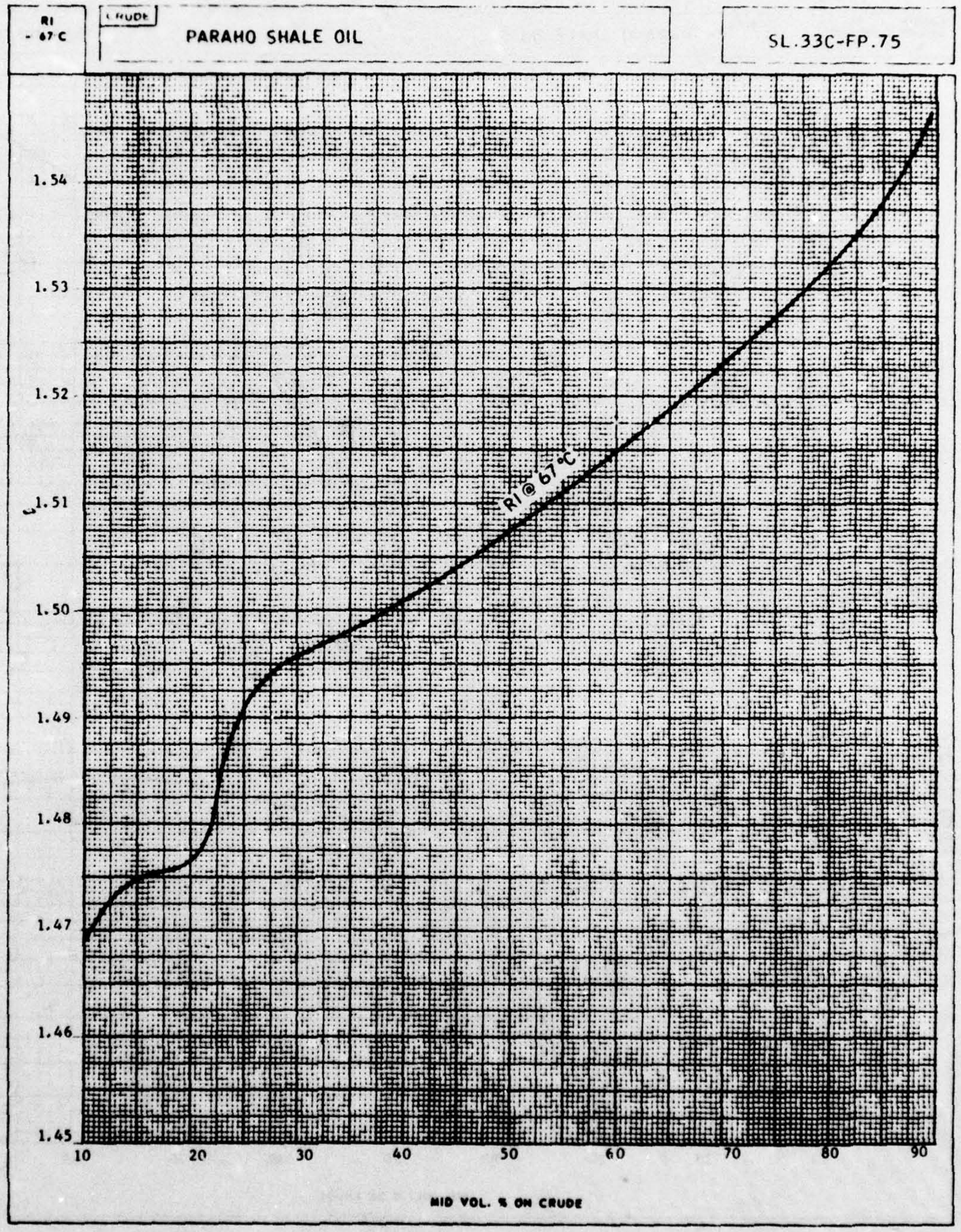

MID LIQ. VOL. %, VS
GRAVITY °API
SULFUR
TEMP. °F VT
CRUDE
PARAHO SHALE OIL
SL.33C-FP.75
Temperature
°API
Sulfur
LV % DISTILLED OR MID LV %
GRAPH NO. 1


GRAPH 2
GRAPH NO. 2
KEROSENES
CRUDE
PARAHO SHALE OIL
SL.33C-FP.75
FREEZE POINT F
SMOKE POINT mm
LUM NO.
17
16
15
14
13
12
11
10
40
30
20
10
0
Smoke Pt.
LUM No.
0
1
2
3
4
5
6
7
8
9
10
MID VOL. % ON CRUDE


GRAPH NO 3
MIDDLE DISTILLATES AND GAS OILS
CRUDE
PARAHO SHALE OIL
SL.33C-FP.75
ANILINE POINT °F
POUR °F
CLOUD °F
140
120
100
80
60
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
Pour Pt.
Aniline Point
0
10
20
30
40
50
60
70
80
90
100
MID VOL. % ON CRUDE
GRAPH 3

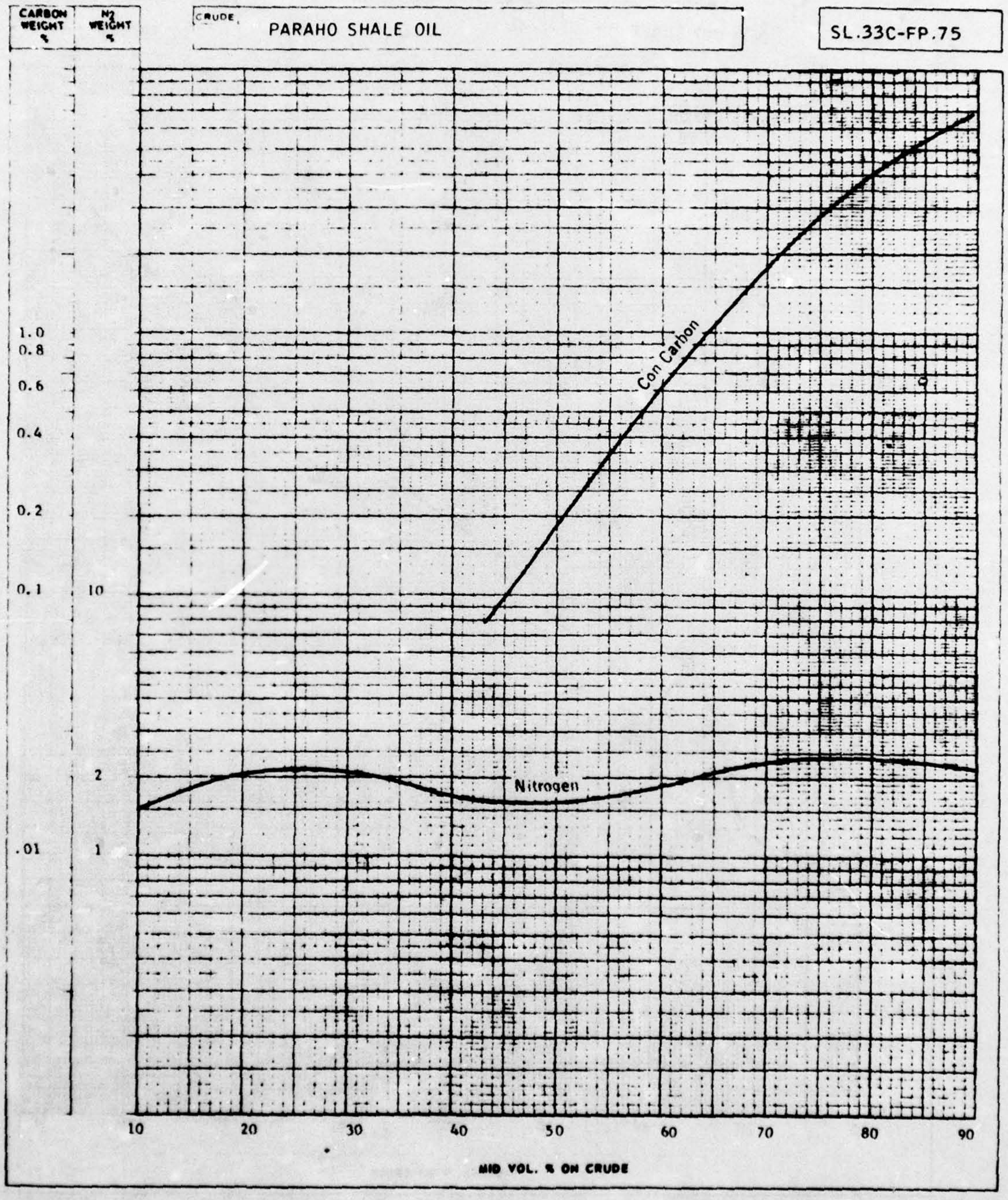
GRAPH NO. 4

MIDDLE DISTILLATES AND GAS OILS



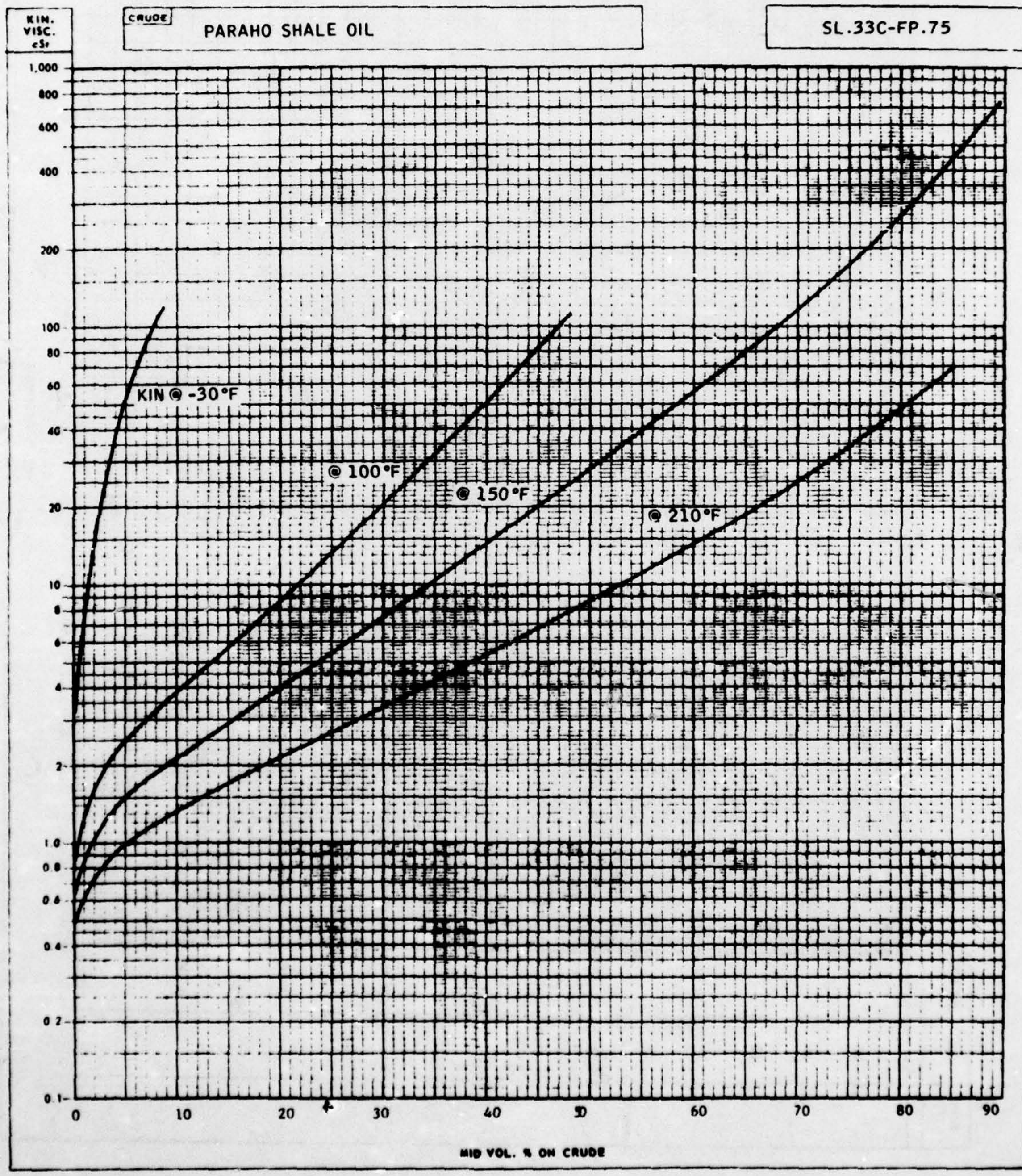
GRAPH. NO. 5

MIDDLE DISTILLATES AND GAS OILS



GRAPH NO. 6

MIDDLE DISTILLATES AND GAS OILS

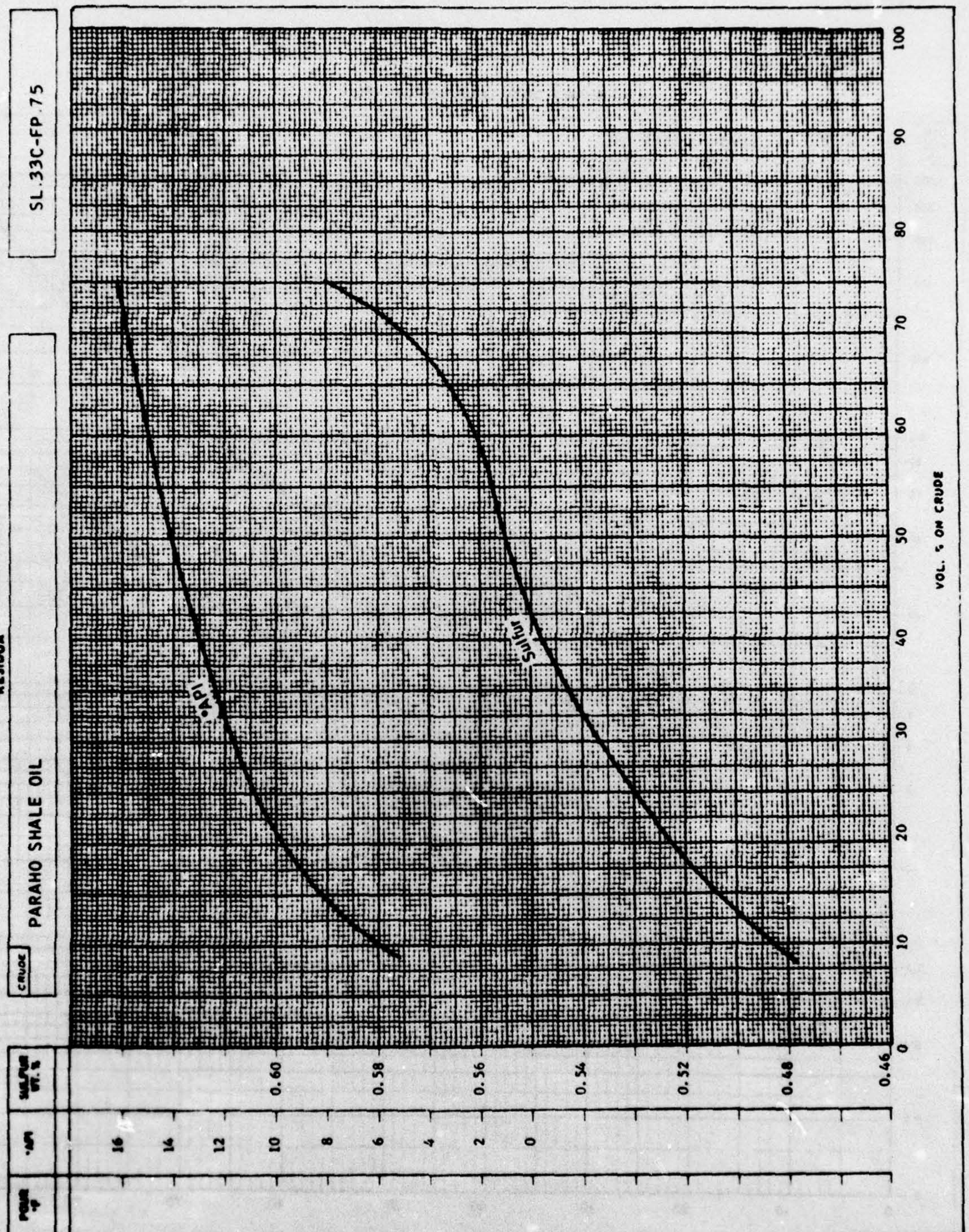


AD-A036 190 EXXON RESEARCH AND ENGINEERING CO LINDEN N J GOVERNME--ETC F/G 7/1
EVALUATION OF METHODS TO PRODUCE AVIATION TURBINE FUELS FROM SY--ETC(U)
MAY 76 C D KALFADELIS F33615-74-C-2036

UNCLASSIFIED EXXON/GRU.2PEA.76 AFAPL-TR-75-10-VOL-2 NL

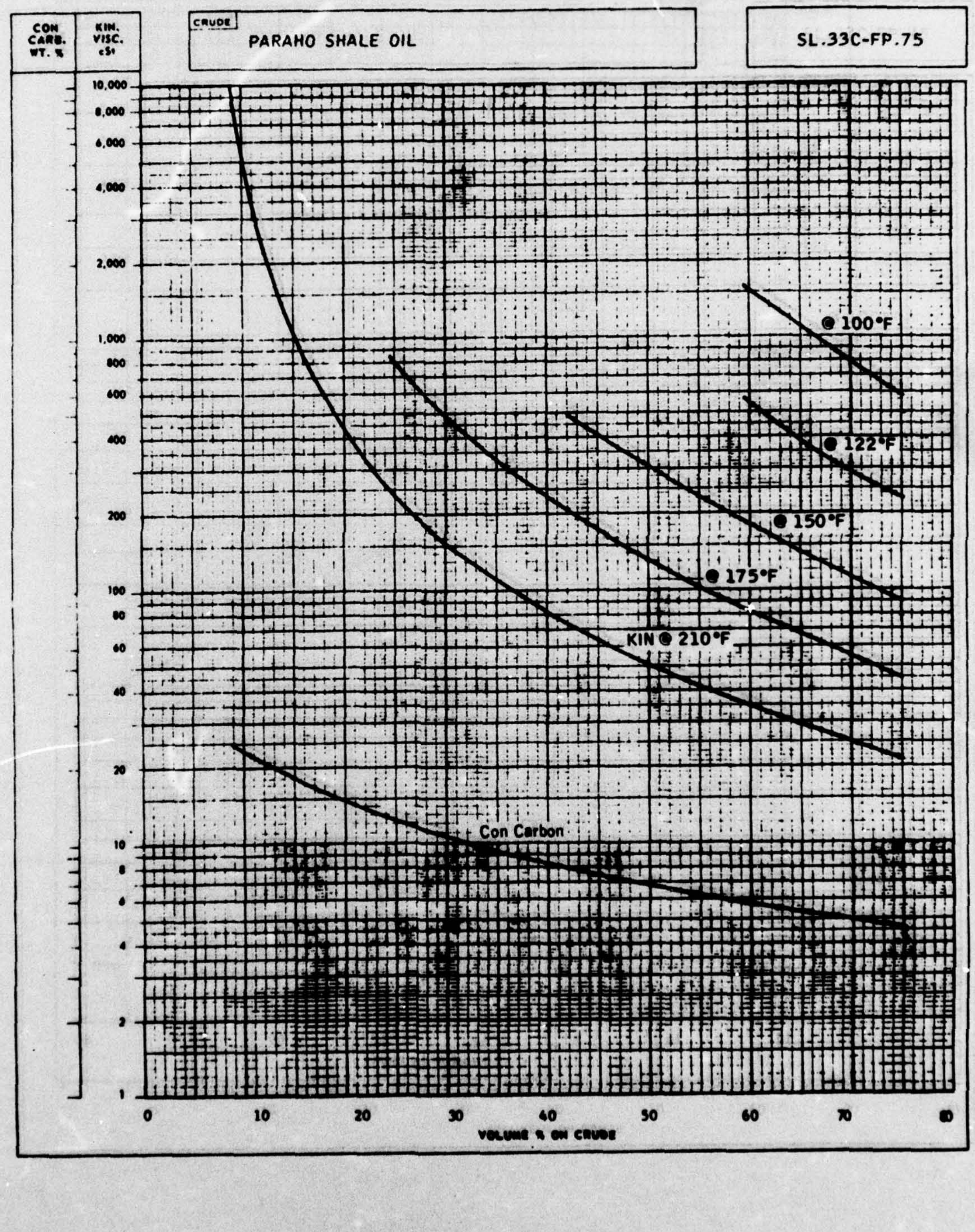
3 OF 4
AD
A036190

GRAPH 7


GRAPH NO. 7
RESIDUA
CRUDE
PARAHO SHALE OIL
SL.33C-FP.75
POUR °F
°API
SULFUR WT. %
16
14
12
10
8
6
4
2
0
0.60
0.58
0.56
0.54
0.52
0.48
0.46
°API
Sulfur
0
10
20
30
40
50
60
70
80
90
100
VOL. % ON CRUDE

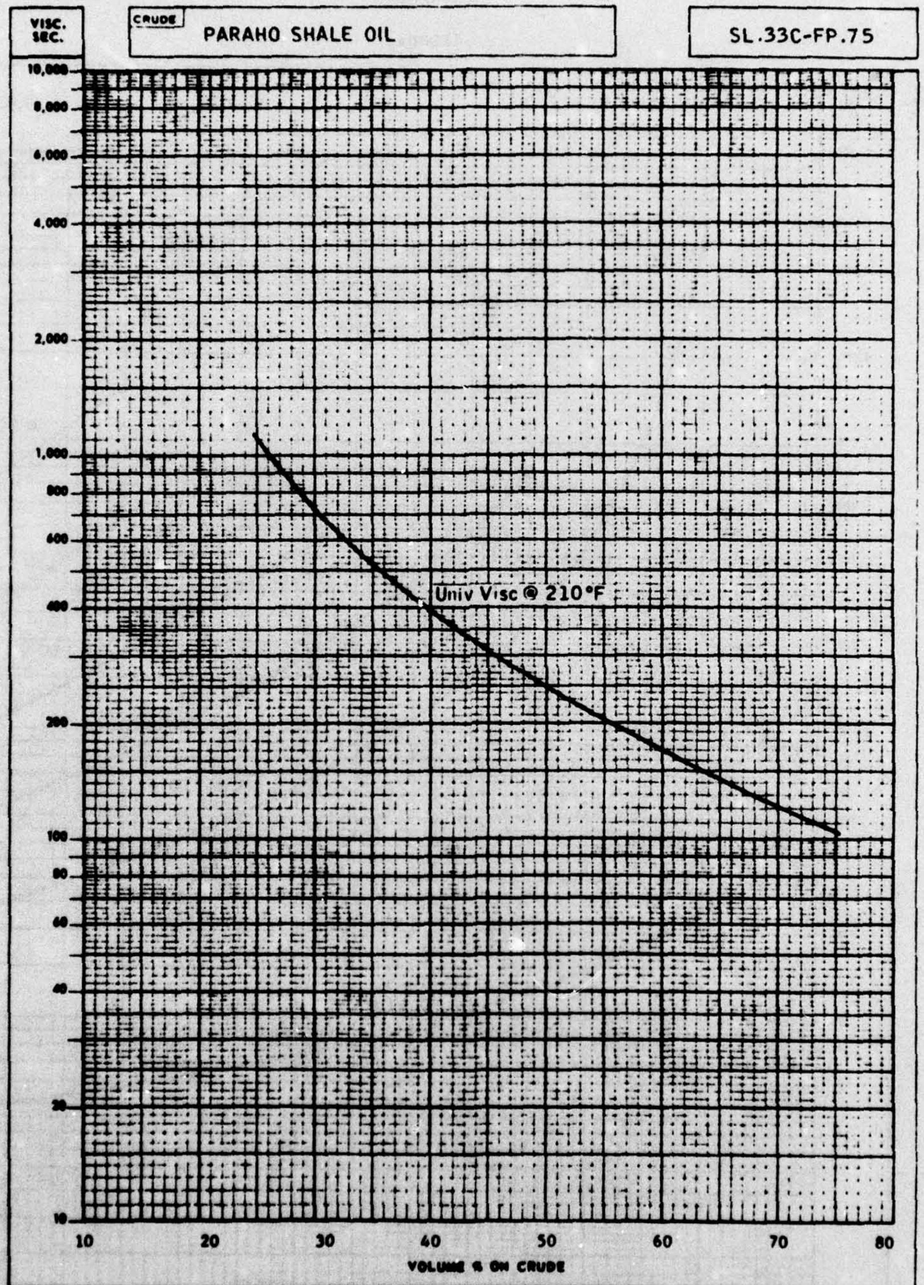
GRAPH NO. 8

RESIDUA



GRAPH NO. 9

RESIDUA



APPENDIX VI

CRUDE ASSAY - TOSCO SHALE OIL

CRUDE:	SHALE OIL - TOSCO
COUNTRY:	Colorado
REPRESENTATIVE OF:	Production from pilot plant at Rifle, Colorado

FILE NO.:	SL. 17C-FP. 75
REPORT DATE:	October 28, 1975
REPORT BY:	Gary N. Williams

EXXON RESEARCH & ENGINEERING CO.
ENGINEERING INFORMATION CENTER
FLORHAM PARK, N.J.

DATE RECEIVED:	3-4-75
DATE DISTILLED:	7-14-75
LAB ASSAY NO.:	2033
COST CENTER:	2524-704 (5800-712160)
CARD NOS.:	

ASSAY RUN BY:

EXXON COMPANY, U.S.A.
REFINING DEPARTMENT
REFINERY LABORATORY
BAYTOWN, TEXAS

SPONSORED BY:

Exxon Research and Engineering Company
Linden, New Jersey

TABLE 1

CRUDE	
SHALE OIL - TOSCO	SL.17C-FP.75

WHOLE CRUDE DATA

GRAVITY		°API	21.0
SPECIFIC GRAVITY		60/60	0.9279
SULFUR		WT. %	0.67
MERCAPTAN SULFUR		WT. PPM	47
POUR POINT		°F	70
NITROGEN		WT. %	1.85
WATER AND SEDIMENT		VOL. %	0.2
SALT CONTENT, NaCl		PTB	
REID VAPOR PRESSURE		PSI	0.2
H_2S (DISSOLVED)		WT. PPM	0
NEUT. NO. (D664)		mg KOH/gm	0.9
VISCOSITIES:	KINEMATIC @	122°F, cSt	
		100°F, cSt	27.1
		80°F, cSt	
		60°F, cSt	
		40°F, cSt	
	SAYBOLT UNIVERSAL @	122°F, SEC	
		100°F, SEC	128.6
		80°F, SEC	
		60°F, SEC	
		40°F, SEC	

LIGHT HYDROCARBONS

% ON CRUDE	WEIGHT	VOLUME
ETHANE AND LIGHTER		
PROPANE		
ISO BUTANE		
NORMAL BUTANE		
ISO PENTANE		
NORMAL PENTANE		

TABLE 2

SHALE OIL TOSCO DATA INPUT AND CALCULATIONS 21.0 DEG API SL.17C-FP.25

TEMPERATURE DEG F	TEMPERATURE DEG C	NORM. VOL. PCT ON CRUDE	NORM. VOL. PCT CUM	NORM. VOL. PCT MID	GRAVITY DEG API	GRAVITY SPECIFIC	SUM OF SPEC GRAV X VOL PCT	RI AT 67 DEG C	DEG F AN. PT.	SUM OF VOL PCT X AN. PT.
C_2		0.0	0.0	0.0	246.8	0.3740	0.0			
C_3		0.0	0.0	0.0	147.1	0.5079	0.0			
iC_4		0.0	0.0	0.0	119.8	0.5631	0.0			
68 nC_4	20.0	0.04	0.04	0.02	110.8	0.5840	0.02336			
iC_5		0.03	0.07	0.05	94.9	0.6250	0.04211			
nC_5		0.02	0.09	0.08	92.7	0.6311	0.05473			
158	70.0	0.51	0.60	0.34	61.7	0.7324	0.42826			
185	85.0	0.30	0.90	0.75	63.0	0.7275	0.64651			
212	100.0	0.70	1.60	1.25	60.9	0.7354	1.16132			
248	120.0	1.10	2.70	2.15	54.0	0.7628	2.00040			
275	135.0	1.40	4.10	3.40	54.9	0.7591	3.06317			
302	150.0	2.20	6.30	5.20	50.7	0.7766	4.77173			
320	160.0	1.90	8.20	7.25	48.2	0.7874	6.26784	1.4185	84	159.6
347	175.0	2.40	10.60	9.40	45.2	0.8008	8.18974	1.4265	74	337.2
374	190.0	2.20	12.80	11.70	42.5	0.8132	9.97882	1.4318	73	497.8
401	205.0	1.60	14.40	13.60	41.1	0.8198	11.29052	1.4355	80	625.8
428	220.0	1.50	15.90	15.15	38.9	0.8304	12.53612	1.4396	92	763.8
455	235.0	1.70	17.60	16.75	37.8	0.8358	13.95697	1.4440	94	923.6
482	250.0	2.10	19.70	18.65	35.6	0.8468	15.73524	1.4497	94	1121.0
509	265.0	2.00	21.70	20.70	33.2	0.8591	17.45351	1.4572	91	1303.0
536	280.0	2.30	24.00	22.85	31.0	0.8708	19.45627	1.4649	91	1512.3
563	295.0	2.30	26.30	25.15	28.5	0.8844	21.49033	1.4731	100	1742.3
590	310.0	2.70	29.00	27.65	28.0	0.8871	23.88562	1.4745	103	2020.4
617	325.0	2.60	31.60	30.30	26.6	0.8950	26.21263	1.4785	97	2272.6
650	343.3	3.40	35.00	33.30	24.3	0.9082	29.30055	1.4873	94	2592.2
671	355.0	2.20	37.20	36.10	22.3	0.9200	31.32460	1.4965	98	2807.8
698	370.0	3.30	40.50	38.85	21.1	0.9273	34.38455	1.5012	103	3147.7
725	385.0	2.50	43.00	41.75	20.4	0.9315	36.71338	1.5042	107	3415.2
752	400.0	3.70	46.70	44.85	19.7	0.9358	40.17599	1.5066	113	3833.3
779	415.0	3.30	50.00	48.35	19.1	0.9396	43.27658	1.5091	125	4245.8
806	430.0	3.20	53.20	51.60	18.3	0.9446	46.29927	1.5112	130	4661.8
833	445.0	3.60	56.80	55.00	17.7	0.9484	49.71347	1.5143	130	5129.8
851	455.0	2.20	59.00	57.90	16.7	0.9548	51.81400	1.5175	127	5409.2
887	475.0	4.70	63.70	61.35	16.0	0.9593	56.32280	1.5227	121	5977.9
914	490.0	3.60	67.30	65.50	15.2	0.9646	59.79520	1.5295	114	6388.3
950	510.0	4.80	72.10	69.70	13.9	0.9732	64.46645	1.5357	105	6892.3
968	520.0	2.10	74.20	73.15	12.9	0.9799	66.52426	1.5402	98	7098.1
995	535.0	3.20	77.40	75.80	12.6	0.9820	69.66652	1.5435	96	7405.3
1022	550.0	2.60	80.00	78.70	12.1	0.9854	72.22850	1.5471	95	7652.3
1049	565.0	2.40	82.40	81.20	11.4	0.9902	74.60498	1.5497	94	7877.9
1049+	565.0+	17.60	100.00	91.20	5.4	1.0336	92.79636			

TABLE 3

SHALE OIL TOSCO   DATA INPUT AND CALCULATIONS   21.0 DEG API   SL.17C-FP.75

TEMPERATURE DEG F	TEMPERATURE DEG C	CALC WT PCT ON CRUDE	NORM WT PCT ON CRUDE	NORM WT PCT CUM	NORM WT PCT MID	SUM WT PCT SULFUR X NORM WT PCT	WT PCT SULFUR	WT PCT CON CARBON	SUM WT PCT CON CARBON X NORM WT PCT	WT PCT NITROGEN	SUM WT PCT NITROGEN X NORM WT PCT
*	C_2	0.0	0.0	0.0	0.0						
	C_3	0.0	0.0	0.0	0.0						
	iC_4	0.0	0.0	0.0	0.0						
68	nC_4 20.0	0.03	0.03	0.03	0.01						
	iC_5	0.02	0.02	0.05	0.04	0.011	0.5400				
	nC_5	0.01	0.01	0.06	0.05	0.018	0.5400				
158	70.0	0.40	0.40	0.46	0.26	0.240	0.5500				
185	85.0	0.24	0.24	0.70	0.58	0.393	0.6500				
212	100.0	0.55	0.55	1.25	0.97	0.831	0.7900				
248	120.0	0.90	0.90	2.16	1.70	1.889	1.1700				
275	135.0	1.15	1.15	3.30	2.73	2.793	0.7900				
302	150.0	1.84	1.84	5.14	4.22	4.598	0.9800				
320	160.0	1.61	1.61	6.75	5.95	5.936	0.8300				
347	175.0	2.07	2.07	8.83	7.79	7.531	0.7700				
374	190.0	1.93	1.93	10.75	9.79	9.227	0.8800				
401	205.0	1.41	1.41	12.17	11.46	10.344	0.7900				
428	220.0	1.34	1.34	13.51	12.84	11.351	0.7500				
455	235.0	1.53	1.53	15.04	14.27	12.606	0.8200				
482	250.0	1.92	1.92	16.96	16.00	14.120	0.7900			0.9600	1.8397
509	265.0	1.85	1.85	18.81	17.88	15.768	0.8900			1.1700	4.0061
536	280.0	2.16	2.16	20.97	19.89	17.819	0.9500			1.3900	7.0061
563	295.0	2.19	2.19	23.16	22.06	19.616	0.9200			1.6200	10.5570
590	310.0	2.58	2.58	25.74	24.45	21.552	0.7500			1.8000	15.2033
617	325.0	2.51	2.51	28.25	26.99	23.282	0.6900			1.9400	20.0681
650	343.3	3.33	3.33	31.58	29.91	25.778	0.7500			2.0200	26.7899
671	355.0	2.18	2.18	33.76	32.67	27.414	0.7500	0.00	0.0087	2.0300	31.2177
698	370.0	3.30	3.30	37.05	35.40	29.656	0.6800	0.01	0.0285	2.0400	37.9446
725	385.0	2.51	2.51	39.56	38.31	31.287	0.6500	0.01	0.0611	2.0500	43.0893
752	400.0	3.73	3.73	43.29	41.43	33.638	0.6300	0.04	0.1917	2.0600	50.7761
779	415.0	3.34	3.34	46.64	44.97	35.643	0.6000	0.13	0.6261	2.0600	57.6591
806	430.0	3.26	3.26	49.89	48.26	37.565	0.5900	0.25	1.4404	2.0700	64.4018
833	445.0	3.68	3.68	53.57	51.73	39.625	0.5600	0.42	2.9857	2.0800	72.0547
851	455.0	2.26	2.26	55.84	54.70	40.915	0.5700	0.60	4.3439	2.1000	76.8082
887	475.0	4.86	4.86	60.70	58.27	43.831	0.6000	0.90	8.7168	2.1400	87.2061
914	490.0	3.74	3.74	64.44	62.57	46.263	0.6500	1.47	14.2175	2.1800	95.3635
950	510.0	5.03	5.03	69.47	66.95	49.484	0.6400	2.36	26.0974	2.2400	
968	520.0	2.22	2.22	71.69	70.58	50.837	0.6100	3.50	33.8589	2.3200	
995	535.0	3.39	3.39	75.07	73.38	52.903	0.6100	4.35	50.2819	2.3800	
1022	550.0	2.76	2.76	77.84	76.46	54.559	0.6000	6.70	68.7797	2.4400	
1049	565.0	2.56	2.56	80.40	79.12	56.070	0.5900	8.84	91.4196	2.5200	
1049+	565.0+	19.61	19.60	100.00	90.20	66.460	0.5300	25.20	585.4272	2.3200	
		100.01									

SHALE OIL TOSCO CALCULATED BLENDS 21.0 DEG API TABLE 4 SL.17C-FP.75

TEMP. RANGE F		VOLUME% INIT	VOLUME% FINAL	VOLUME YIELD	MID VOLUME	GRAVITY DEG API	GRAVITY SPECIFIC	NORM WT PCT	SULFUR WT PCT	RI AT 67 DEG C	CON CARBON	WT PCT NITROGEN	ANILINE PT
68	198	0.04	0.60	0.56	0.32	64.20	0.7230	0.44	0.5497				
68	185	0.04	0.90	0.86	0.47	63.78	0.7246	0.67	0.5945				
68	212	0.04	1.60	1.56	0.82	62.48	0.7295	1.23	0.6775				
68	248	0.04	2.70	2.66	1.37	58.83	0.7433	2.13	0.8365				
68	302	0.04	6.30	6.26	3.17	55.05	0.7585	5.12	0.8985				
68	374	0.04	12.80	12.76	6.42	49.86	0.7802	10.73	0.8601				
198	212	0.60	1.60	1.00	1.10	61.53	0.7331	0.78	0.7483				
185	302	0.90	6.30	5.40	3.60	53.73	0.7639	4.45	0.9460				
212	248	1.60	2.70	1.10	2.15	54.00	0.7629	0.90	1.1700				
212	302	1.60	6.30	4.70	3.95	52.70	0.7682	3.99	0.9682				
248	302	2.70	6.30	3.60	4.50	52.31	0.7698	2.99	0.9071				
248	374	2.70	12.80	10.10	7.75	47.63	0.7899	8.60	0.8536				
302	374	6.30	12.80	6.50	9.55	45.13	0.8011	5.61	0.8250	1.4260			77
302	401	6.30	14.40	8.10	10.35	44.32	0.8048	7.02	0.8180	1.4278			77
302	455	6.30	17.60	11.30	11.95	42.58	0.8129	9.90	0.8091	1.4318			82
302	509	6.30	21.70	15.40	14.00	40.33	0.8235	13.67	0.8174	1.4376			85
302	536	6.30	24.00	17.70	15.15	39.06	0.8296	15.82	0.8355	1.4411			85
302	698	6.30	40.50	34.20	23.40	31.92	0.8659	31.91	0.7852	1.4627			92
320	650	8.20	35.00	26.80	21.60	33.14	0.8594	24.82	0.7994	1.4583			91
347	698	10.60	40.50	29.90	25.55	30.01	0.8761	28.23	0.7838	1.4684			94
374	482	12.80	19.70	6.90	16.25	38.11	0.8343	6.20	0.7887	1.4428			90
374	536	12.80	24.00	11.20	18.40	35.72	0.8462	10.21	0.8412	1.4499			91
401	509	14.40	21.70	7.30	18.05	36.11	0.8442	6.64	0.8167	1.4484			93
401	650	14.40	35.00	20.60	24.70	30.35	0.8743	19.41	0.7952	1.4666			95
428	536	15.90	24.00	8.10	19.95	34.12	0.8543	7.46	0.8673	1.4547			92
509	590	21.70	29.00	7.30	25.35	29.09	0.8811	6.93	0.8344	1.4710		1.6154	98
536	650	24.00	35.00	11.00	29.50	26.61	0.8949	10.61	0.7503	1.4791		1.8649	98
590	650	29.00	35.00	6.00	32.00	25.29	0.9025	5.84	0.7242	1.4835		1.9856	95
590	698	29.00	40.50	11.50	34.75	23.49	0.9130	11.31	0.7163	1.4911	0.00	2.0100	98
650	752	35.00	46.70	11.70	40.85	20.73	0.9295	11.72	0.6707	1.5027	0.02	2.0466	106
650	851	35.00	59.00	24.00	47.00	19.34	0.9381	24.26	0.6239	1.5078	0.18	2.0617	117
650	1049	35.00	82.40	47.40	58.70	16.54	0.9558	48.82	0.6205	1.5219	1.87	2.1762	112
752	851	46.70	59.00	12.30	52.85	18.05	0.9462	12.54	0.5803	1.5127	0.33	2.0757	128
779	995	50.00	77.40	27.40	63.70	15.42	0.9631	28.44	0.6069	1.5268	1.75	2.1866	115
851	950	59.00	72.10	13.10	65.55	15.01	0.9658	13.63	0.6285	1.5293	1.60	2.1879	113
851	1049	59.00	82.40	23.40	70.70	13.78	0.9740	24.56	0.6171	1.5363	3.55	2.2893	105
950	1049	72.10	82.40	10.30	77.25	12.25	0.9843	10.93	0.6028	1.5452	5.98	2.4158	96
995	1049	77.40	82.40	5.00	79.90	11.76	0.9877	5.32	0.5952	1.5483	7.73	2.4785	95

RESIDUE

DEG F TEMP	YLD% VOLUME	GRAVITY DEG API	GRAVITY SPECIFIC	YLD WT PCT	WT% SULFUR	WT% CON CARBON	WT% NITROGEN
1049+	17.60	5.4	1.0336	19.60	0.53	25.20	2.32
995+	22.60	6.8	1.0234	24.93	0.54	21.47	2.35
950+	27.90	7.9	1.0154	30.53	0.56	18.32	2.35
851+	41.00	10.1	0.9996	44.16	0.58	13.16	2.30
752+	53.30	11.8	0.9872	56.71	0.58	10.32	2.25
698+	59.50	12.6	0.9817	62.45	0.58	9.30	2.23
650+	65.00	13.4	0.9769	68.42	0.59	8.56	2.22
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	2.19

TABLE 5

CRUDE

SHALE OIL - TOSCO

SL. 17C-FP. 75

GASOLINES & NAPHTHAS

15/5 CUT POINT	°F VT	68/158	68/212	158/212	212/302	248/374	302/374
15/5 CUT POINT	°C VT	20/70	20/100	70/100	100/150	120/190	150/190
YIELD CUT RANGE	VOL. %	0.04-0.6	0.04-1.6	0.6-1.6	1.6-6.3	2.7-12.8	6.3-12.8
YIELD ON CRUDE	VOL. %	0.56	1.56	1.0	4.7	10.1	6.5
MID POINT	VOL. %	0.3	0.8	1.1	4.0	7.8	9.6
GRAVITY	°API	64.2	62.5	61.5	52.7	47.6	45.1
SPECIFIC GRAVITY	60/60	0.7230	0.7294	0.7332	0.7682	0.7901	0.8012
TOTAL SULFUR	WT. %	0.55	0.68	0.75	0.97	0.85	0.82
MERCAPTAN SULFUR	WT. PPM	168	169	170	160	145	140
REID VAPOR PRESSURE	PSI						
RESEARCH OCTANE NUMBER							
CLEAR							
+ 1.5 ml TEL/USG							
+ 3.0 ml TEL/USG							
MOTOR OCTANE NUMBER							
CLEAR							
+ 1.5 ml TEL/USG							
+ 3.0 ml TEL/USG							
VOL. % D + L @ 70°C/158°F							
@ 100°C/212°F							
FBP °F							
ANILINE POINT, °F							77
		GC		GC	GC / HC		HC
PARAFFINS	VOL. %						30.0
NAPHTHENES	VOL. %						52.6
AROMATICS	VOL. %						17.4

TABLE 6

CRUDE	
SHALE OIL - TOSCO	SL. 17C-FP. 75

KEROSENE & TURBO FUELS

15/5 CUT POINT	°F VT	302-401	302-455	302-509	374-482	374-536
15/5 CUT POINT	°C VT	150-205	150-235	150-265	190-250	190-280
YIELD CUT RANGE	VOL. %	6.3-14.4	6.3-17.6	6.3-21.7	12.8-19.7	12.8-24.0
YIELD ON CRUDE	VOL. %	8.1	11.3	15.4	6.9	11.2
MID-POINT	VOL. %	10.4	12.0	14.0	16.2	18.4
GRAVITY	°API	44.3	42.6	40.3	38.1	35.7
SPECIFIC GRAVITY	60/60	0.8049	0.8128	0.8236	0.8343	0.8463
TOTAL SULFUR	WT. %	0.82	0.81	0.82	0.79	0.84
MERCAPTAN SULFUR	WT. PPM	133	118	105	84	78
SMOKE POINT	MM	19	18	17	16	15
LUM. NO.		42.5	41.5	40.0	37.8	34.5
FREEZING POINT	°F	Too Dark				
CLOUD POINT	°F	Too Dark				
POUR POINT	°F	<-80	<-80	-75	-60	-45
ANILINE POINT	°F	77	82	85	90	91
DIESEL INDEX		34	35	34	34	32
COLOR	SAYBOLT					
REFRACTIVE INDEX @ 67°C		1.4278	1.4318	1.4376	1.4428	1.4499
AROMATICS, FIA	VOL. %	Too Dark				
VISCOSITIES:						
KINEMATIC @ -30°F	cSt	4.42	5.70	8.20	12.8	22.0
@ 100°F	cSt	1.02	1.15	1.34	1.60	1.95
@ 210°F	cSt	0.55	0.60	0.67	0.75	0.86

TABLE 7

CRUDE: SHALE OIL - TOSCO

SL. 17C-FP. 75

MIDDLE DISTILLATES

15/5 CUT POINT	°F VT	401-509	509-590	590-650	590-698	320-650	401-650	302-698
15/5 CUT POINT	C VT	205-265	265-310	310-343	310-370	160-343	205-343	150-370
YIELD CUT RANGE	VOL %	14.4-21.7	21.7-29.0	29.0-35.0	29.0-40.5	8.2-35.0	14.4-35.0	6.3-40.5
YIELD ON CRUDE	VOL %	7.3	7.3	6.0	11.5	26.8	20.6	34.2
MID-POINT	VOL %	18.0	25.4	32.0	34.8	21.6	24.7	23.4
GRAVITY	API	36.1	29.1	25.3	23.5	33.1	30.4	31.9
SPECIFIC GRAVITY	60/60	0.8443	0.8811	0.9024	0.9129	0.8597	0.8740	0.8660
TOTAL SULFUR	WT %	0.82	0.83	0.72	0.72	0.80	0.80	0.78
ANILINE POINT	°F	93	98	95	98	91	95	92
DIESEL INDEX		34	29	24	23	30	29	29
CETANE INDEX		43	43	44	44	44	44	43
CLOUD POINT	°F	Too Dark						
POUR POINT	°F	-50	0	35	50	-10	0	10
REFRACTIVE INDEX @ 67°C		1.4484	1.4710	1.4835	1.4911	1.4583	1.4666	1.4627
NEUT. NO. (D-974)	mg KOH/gm	0.64	1.08	1.08				
VISCOSITIES:								
KINEMATIC @ 100°F	cSt	1.92	4.02	8.54	12.3	2.70	3.60	3.20
@ 150°F	cSt	1.22	2.20	3.90	5.10	1.60	2.03	1.84
@ 175°F	cSt							
@ 210°F	cSt	0.84	1.33	2.05	2.51	1.03	1.26	1.16
A.R.		9.4	13.1	14.5				
N.R.		33.4	38.9	41.8				
NITROGEN	WT. %		1.62	1.99	2.01			

TABLE 8

CRUDE: SHALE OIL - TOSCO

SL. 17C-FP. 75

GAS OILS

15 5 CUT POINT	F VT	650-752	752-851	851-950	950-1049	650-851	650-1049	851-1049	995-1049
15 5 CUT POINT	C VT	343-400	400-455	455-510	510-565	343-455	343-565	455-565	535-565
YIELD CUT RANGE	VOL. %	35.0-46.7	46.7-59.0	59.0-72.1	72.1-82.4	35.0-59.0	35.0-82.4	59.0-82.4	77.4-82.4
YIELD ON CRUDE	VOL. %	11.7	12.3	13.1	10.3	24.0	47.4	23.4	5.0
MID-POINT	VOL. %	40.8	52.8	65.6	77.2	47.0	58.7	70.7	79.9
GRAVITY	API	20.7	18.1	15.0	12.2	19.3	16.5	13.8	11.8
SPECIFIC GRAVITY	60 60	0.9297	0.9459	0.9659	0.9847	0.9383	0.9561	0.9738	0.9874
TOTAL SULFUR	WT. %	0.67	0.58	0.63	0.60	0.62	0.62	0.62	0.60
ANILINE POINT	°F	106	128	113	96	117	112	105	35
CON CARBON	WT. %	0.02	0.33	1.60	5.98	0.18	1.87	3.55	7.73
POUR POINT	°F	70	100	105	105	85	95	105	105
REFRACTIVE INDEX 67°C		1.5027	1.5127	1.5293	1.5452	1.5078	1.5219	1.5363	1.5483
NEUT NO.	mg KOH/gm					0.35			
NITROGEN	WT. %	2.05	2.08	2.19	2.42	2.06	2.18	2.29	2.48
VISCOSITIES									
KINEMATIC @ 100°F	cSt	27.0	(153)			64.0			
@ 150°F	cSt	9.00	32.0	142	640	17.0	54.5	268	1000
@ 175°F	cSt								
@ 210°F	cSt	3.83	9.34	27.4	83.5	5.88	14.1	43.5	111
BASIC NITROGEN	WT. %					1.21		1.31	
OXYGEN	WT. %					0.91		0.87	
METALS									
VANADIUM	WT. PPM							<0.1	
NICKEL	WT. PPM							1.4	
IRON	WT. PPM							8.4	
A.R.		18.6	18.8	22.6	26.3				27.1
N.R.		46.8	48.4	52.9	58.9				60.3

TABLE 9

CRUDE	
SHALE OIL - TOSCO	SL. 17C-FP. 75

LUBE DISTILLATES

		WAXY LUBE	DEWAXED LUBE
15/5 CUT POINT	°F VT	779-995	
15/5 CUT POINT	°C VT	415-535	
YIELD CUT RANGE	VOL. %	48.8-78.1	
YIELD ON CRUDE	VOL. %	29.3	
MID-POINT	VOL. %	63.4	
GRAVITY	°API	15.4	
SPECIFIC GRAVITY	60/60	0.9632	
TOTAL SULFUR	WT. %	0.61	
CON CARBON	WT. %	1.65	
ANILINE POINT	°F	115	
REFRACTIVE INDEX @ 67°C		1.5265	
NEUT. NO. (D-974)	mg KOH/gm	0.51	
NITROGEN	WT. %	2.18	
POUR POINT	°F	105	
WAX CONTENT	WT. %	10.6	
WAX MELTING POINT	°F		
VISCOSITY INDEX		<0	
VISCOSITIES:			
KINEMATIC @ 100°F	cSt	(750)	
@ 150°F	cSt	106	
@ 175°F	cSt		
@ 210°F	cSt	22.8	
SAYBOLT UNIVERSAL @ 100°F	SEC	(3474)	
@ 210°F	SEC	110.5	

PHENOL TREATING SUSCEPTIBILITY*	
PHENOL TREATING CHARACTERISTICS OF DEWAXED LUBE CUT	
PHENOL/OIL RATIO	
Treat	VI
RAW STOCK	
1/1	
2/1	
3/1	
VISCOSITY GRAVITY CONSTANT	

*From Established Correlations

Yields on this table are those as cut from still and the inspections are raw data, not correlated

TABLE 10

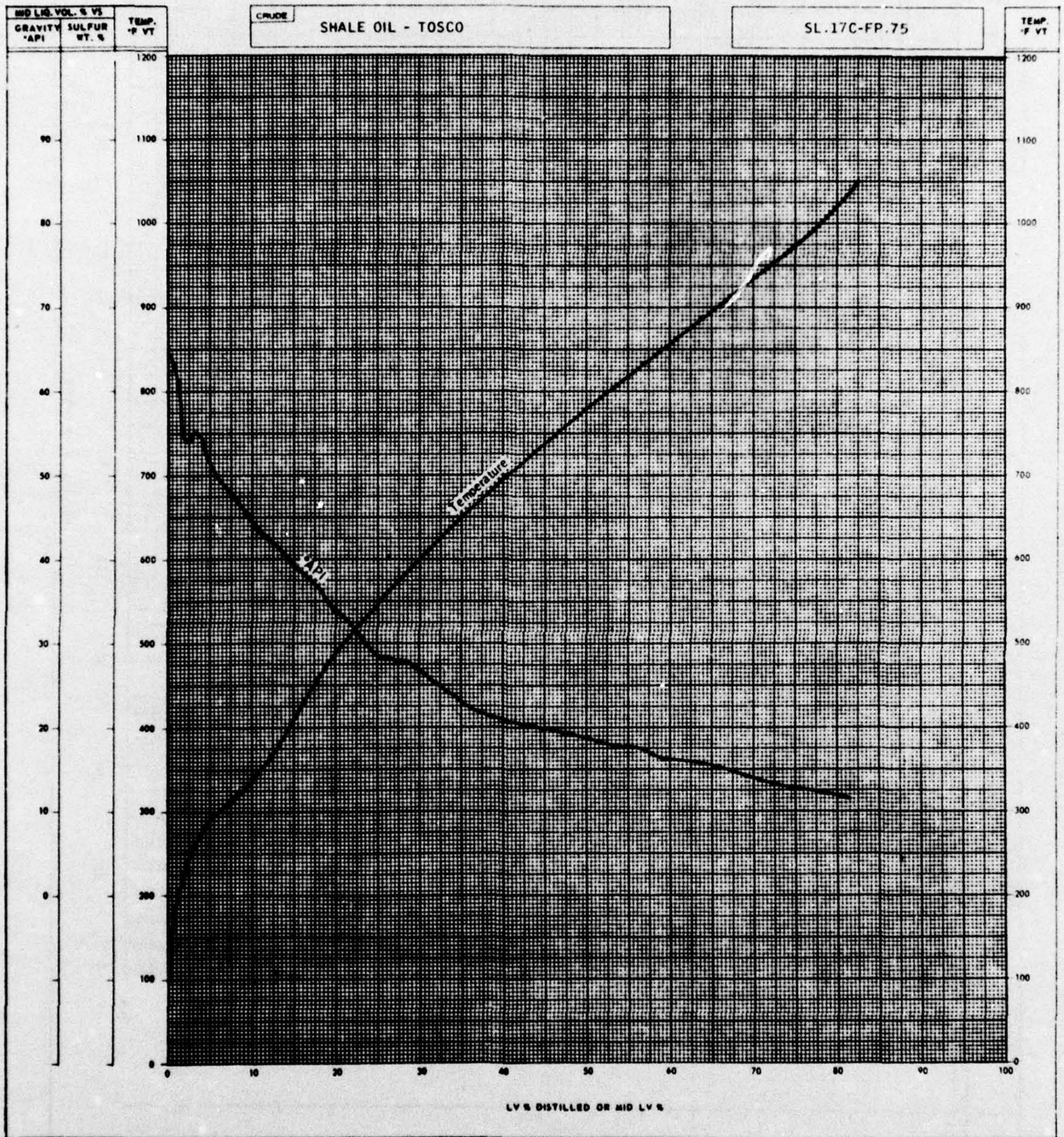
CRUDE: SHALE OIL - TOSCO

SL. 17C-FP. 75

RESIDUA

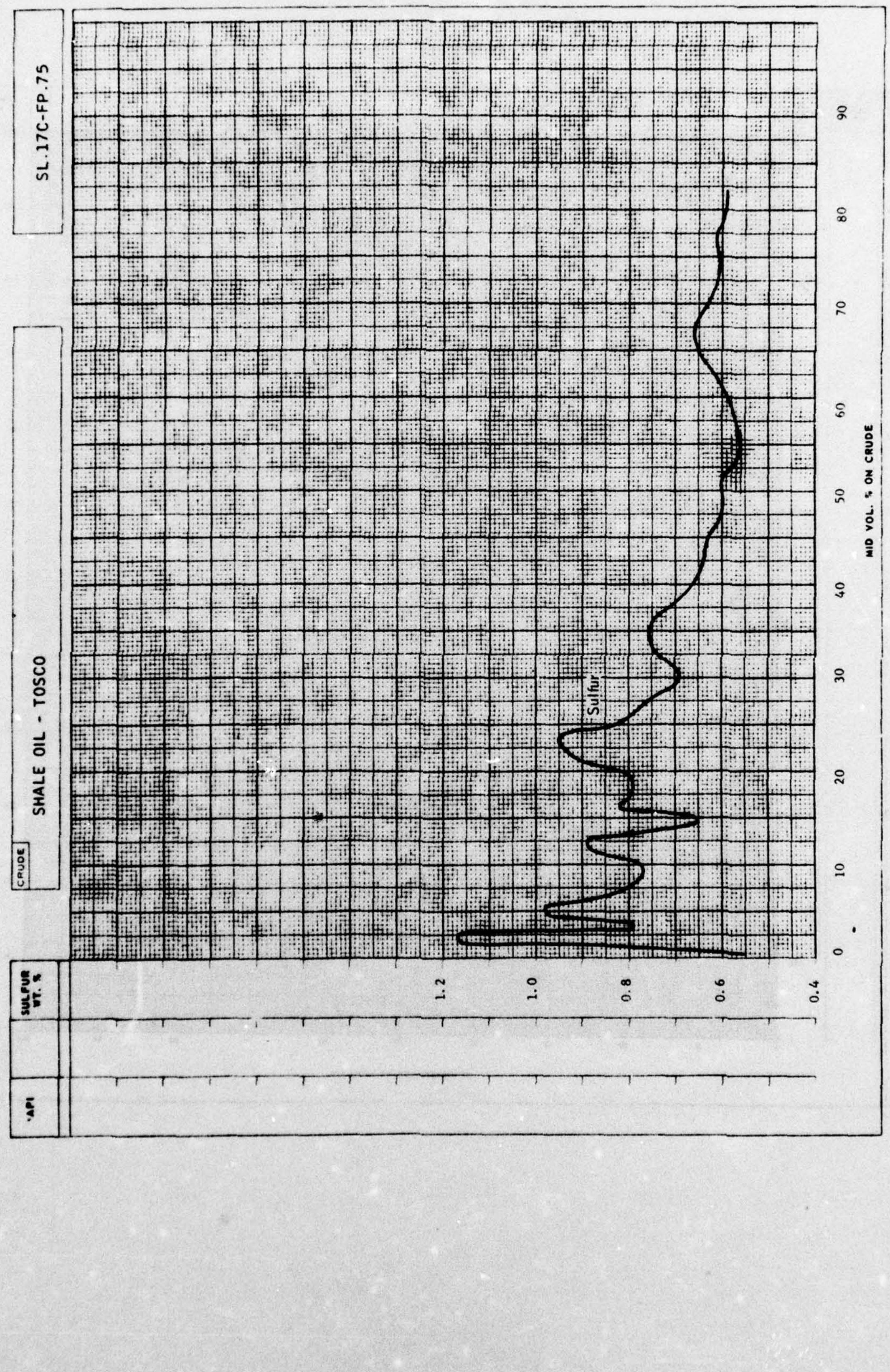
15-5 CUT POINT	°F VT	650+	698+	752+	851+	950+	1049+		
15-5 CUT POINT	°C FT	343+	370+	400+	455+	510+	565+		
YIELD ON CRUDE	VOL. %	65.0	59.5	53.3	41.0	27.9	17.6		
GRAVITY	API	13.4	12.6	11.8	10.1	7.9	5.4		
SPECIFIC GRAVITY	60/60	0.9765	0.9820	0.9874	0.9993	1.0151	1.0336		
TOTAL SULFUR	WT. %	0.59	0.58	0.58	0.58	0.56	0.53		
CON CARBON	WT. %	8.5	9.3	10.3	13.2	18.3	25.2		
NITROGEN	WT. %	2.22	2.23	2.25	2.30	2.35	2.32		
NEUT NO. (D-664)	mg KOH/gm	0.48							
POUR POINT	°F	90	90	95	100	110	125		
VISCOSITIES									
KINEMATIC @ 100°F	cSt	2477	(4600)						
@ 122°F	cSt	800	1360	2800					
@ 150°F	cSt	260	410	755	3094				
@ 175°F	cSt	114	172	283	960	(5600)			
@ 210°F	cSt	45.5	64.0	98.0	258	1100	9324		
FUROL @ 275°F	SEC						289		
@ 300°F	SEC								
UNIVERSAL @ 210°F	SEC	213	299	457	1203	5130			
REDWOOD 1 @ 100°F	SEC	1010							
ABSOLUTE VISC. @ 140°F	POISES								
METALS:									
VANADIUM	WT. PPM	3.8			5.9		13.3		
NICKEL	WT. PPM	5.8			9.0		18.5		
IRON	WT. PPM	48.1			74.6		157.5		
[illegible]	WT. %	3.32					15.0		
[illegible]	WT. %	3.09					13.9		
OXYGEN	WT. %	1.03					1.12		

GRAPH NO. 1


MID LIQ. VOL. % VS
GRAVITY °API
SULFUR WT. %
TEMP. °F VT
CRUDE
SHALE OIL - TOSCO
SL.17C-FP.75
TEMP. °F VT
Temperature
°API
LV % DISTILLED OR MID LV %
GRAPH 1

GRAPH 2

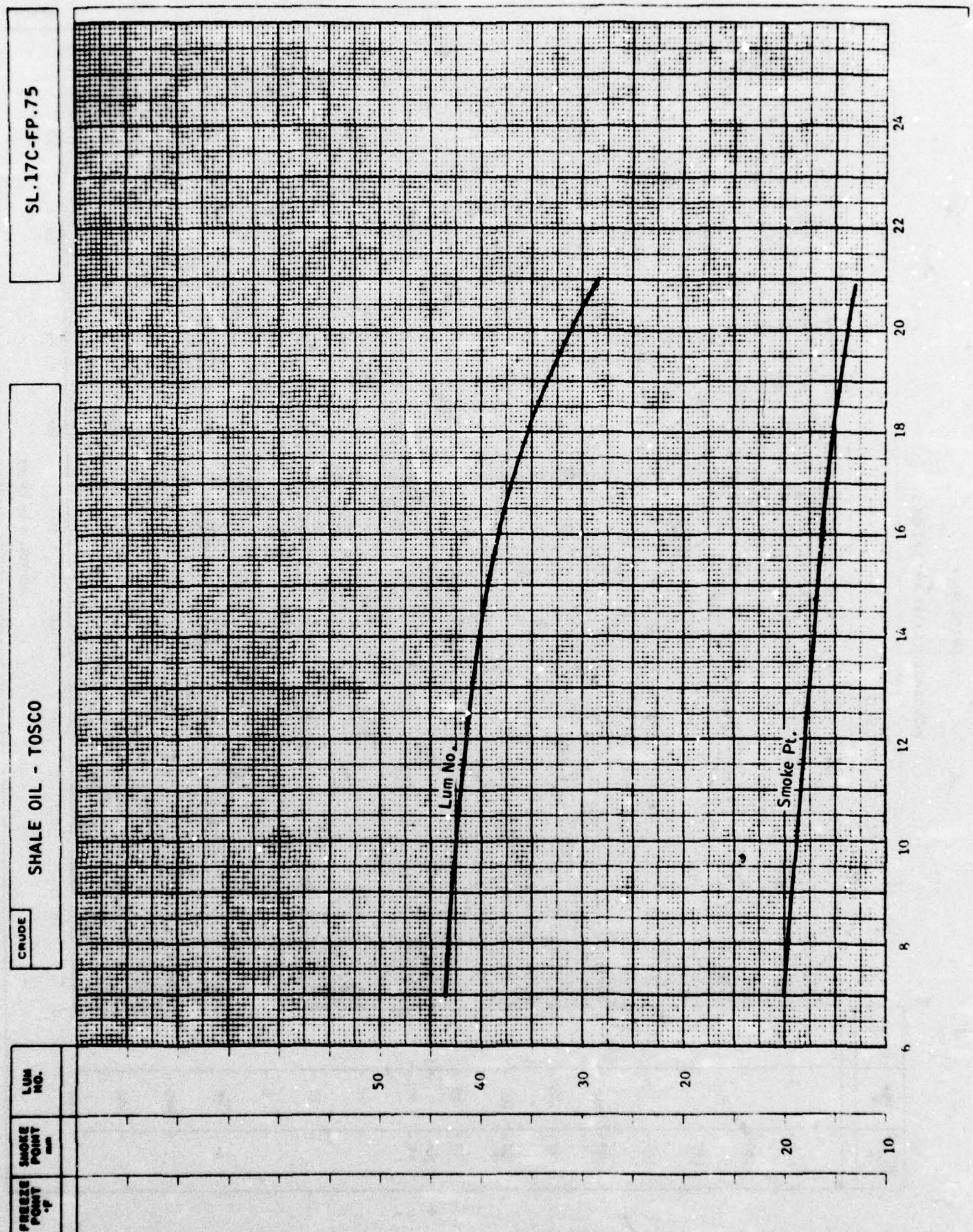
GRAPH NO. 2



GRAPH 3

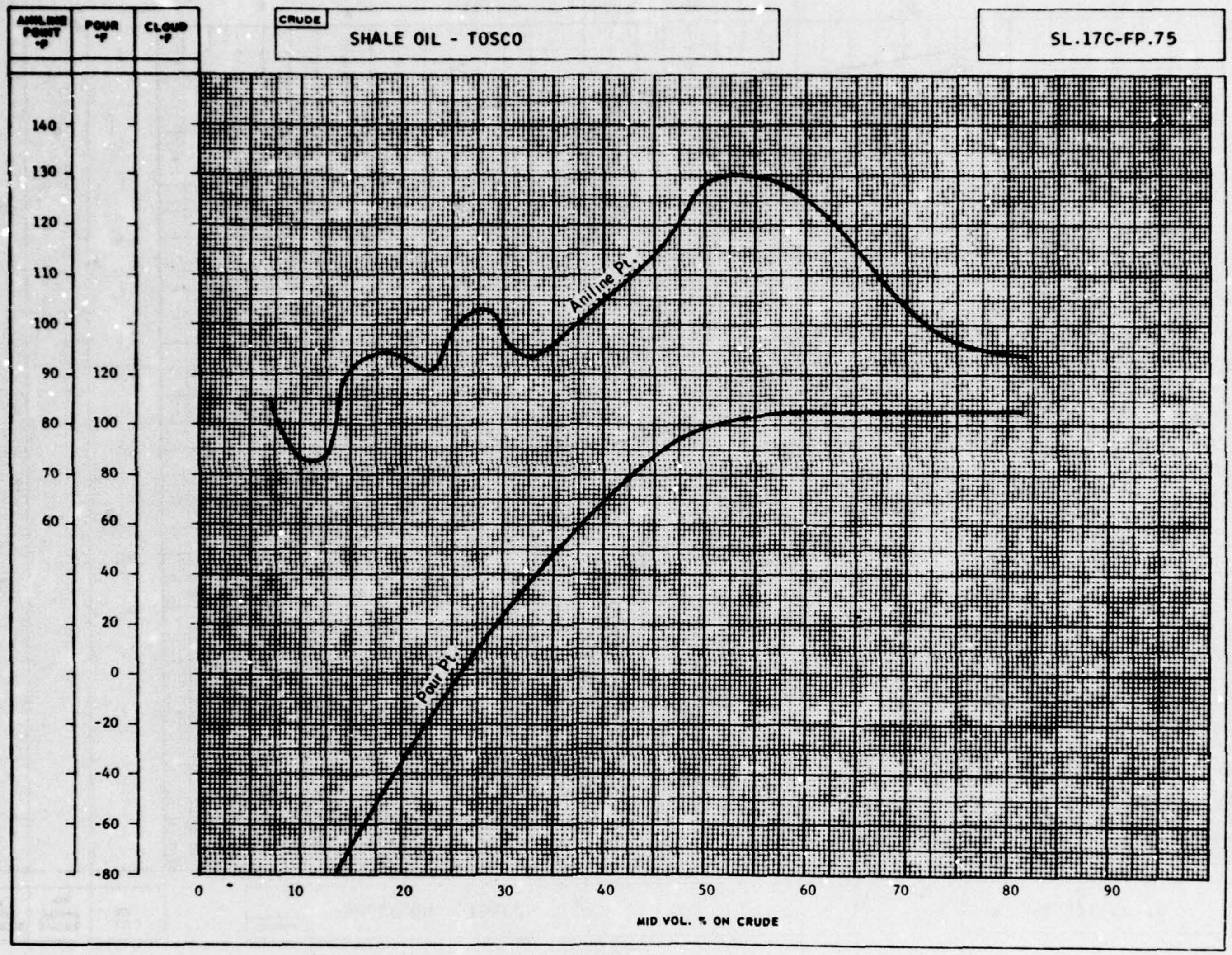
GRAPH NO. 3

KEROSENES



GRAPH NO. 4

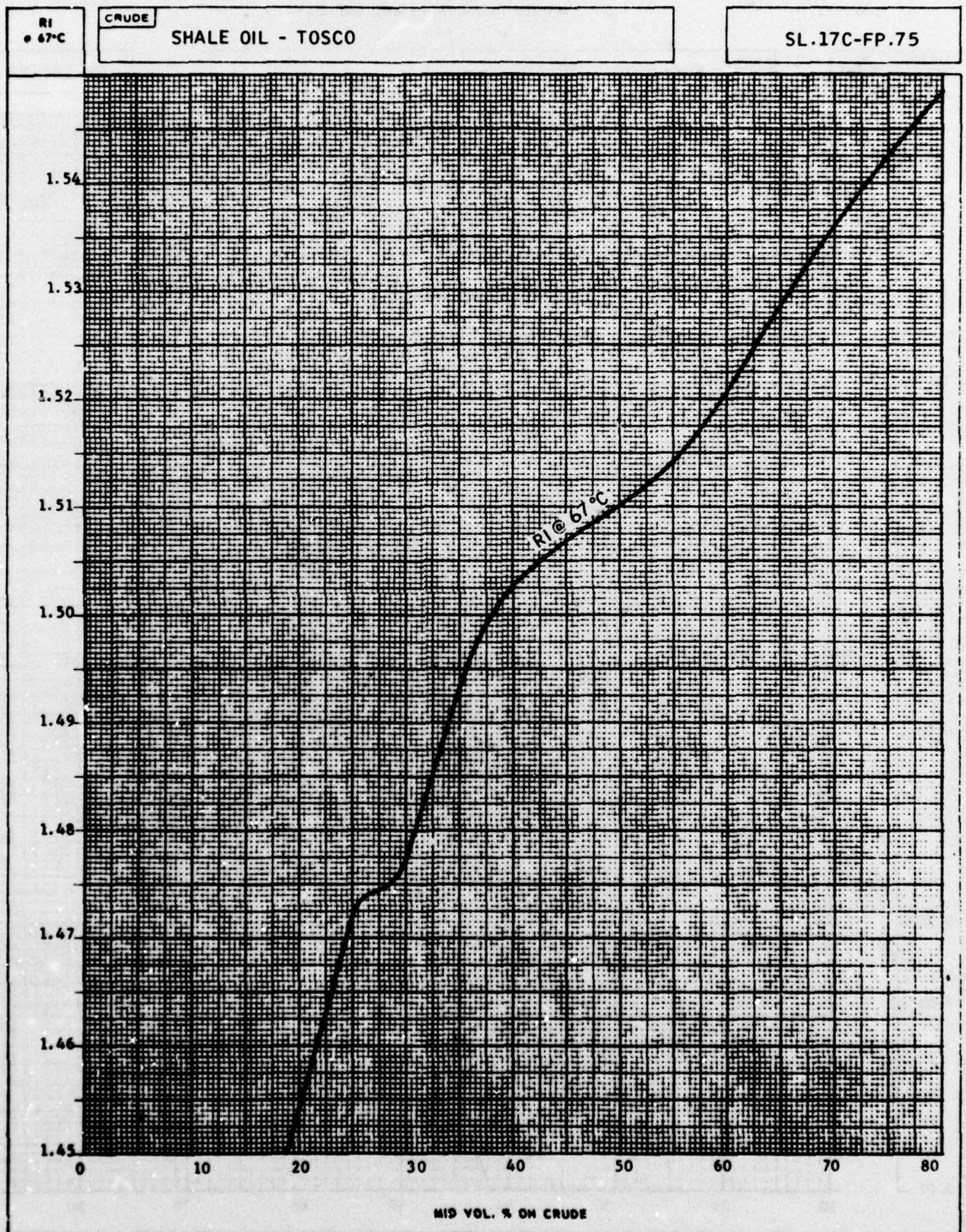
MIDDLE DISTILLATES AND GAS OILS



GRAPH 4

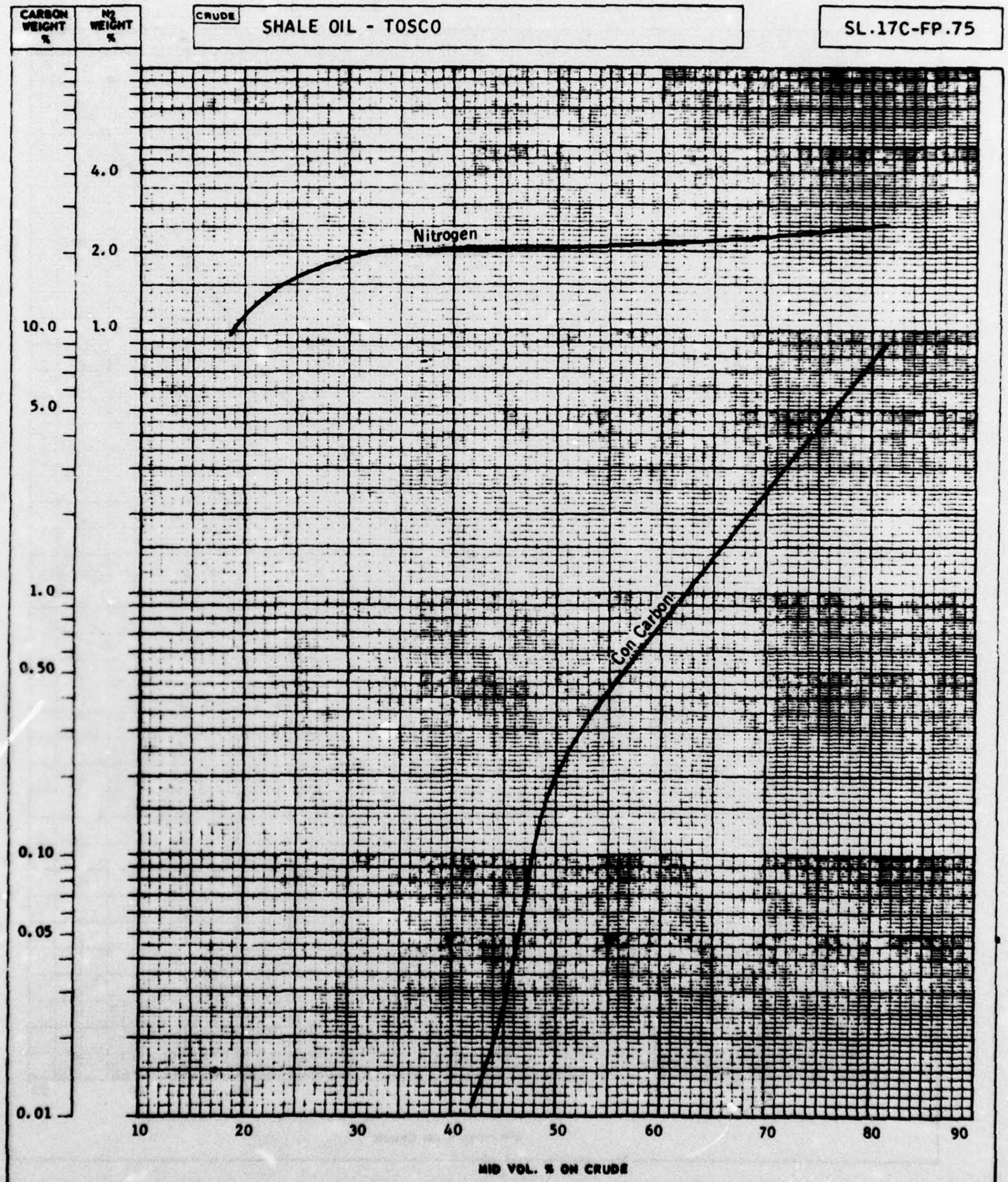
GRAPH NO. 5

MIDDLE DISTILLATES AND GAS OILS



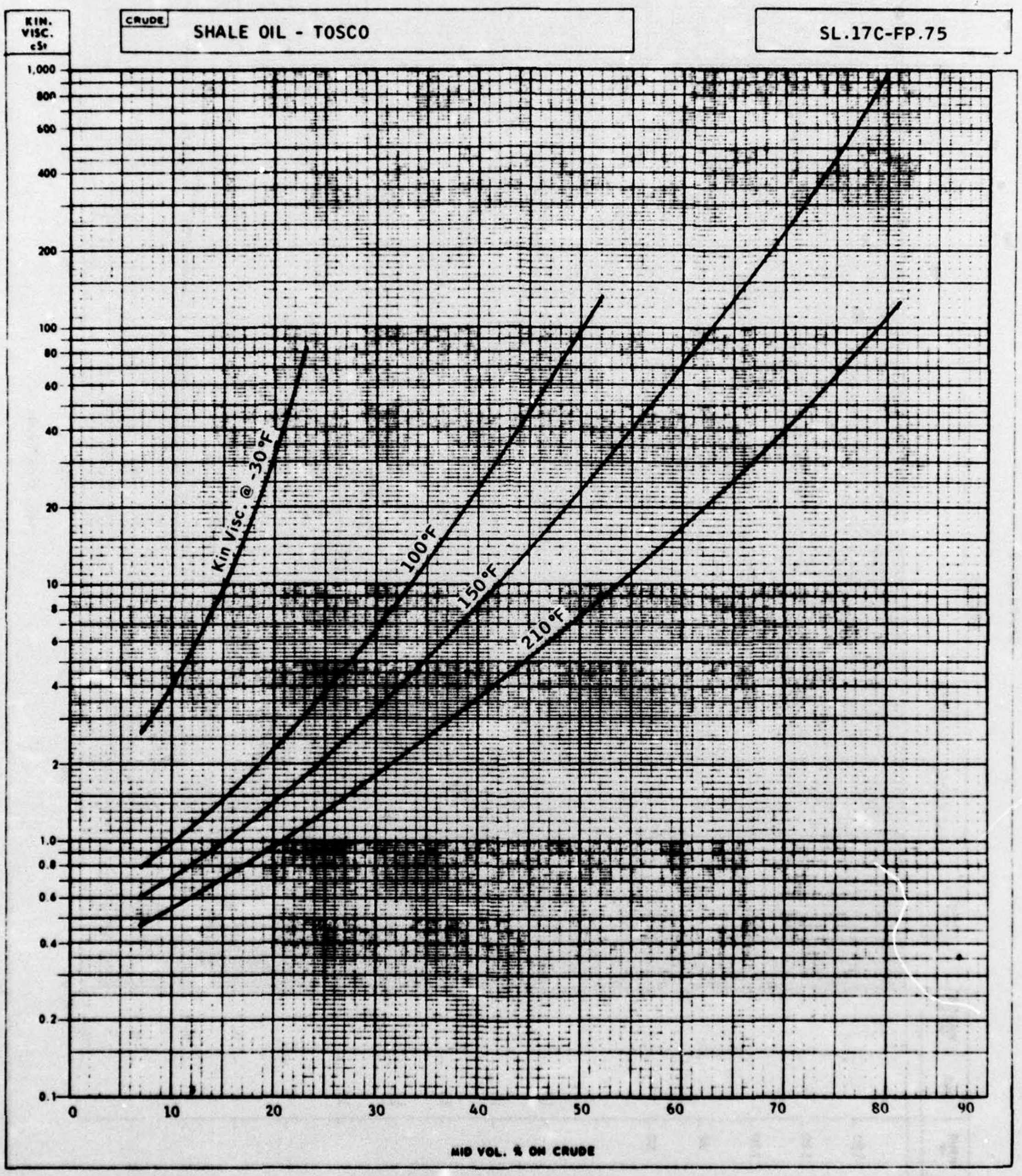
GRAPH. NO. 6

MIDDLE DISTILLATES AND GAS OILS



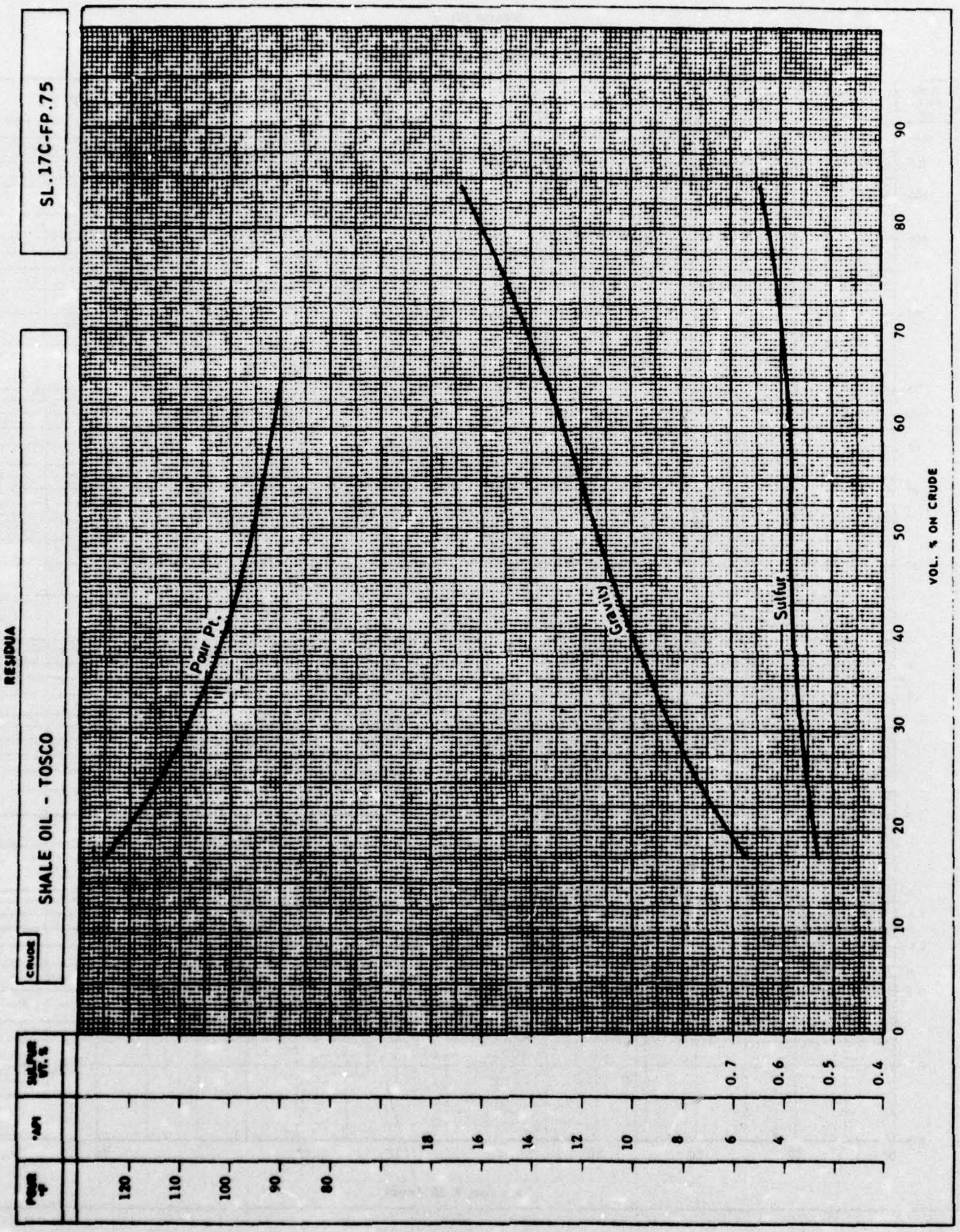
GRAPH NO. 7

MIDDLE DISTILLATES AND GAS OILS



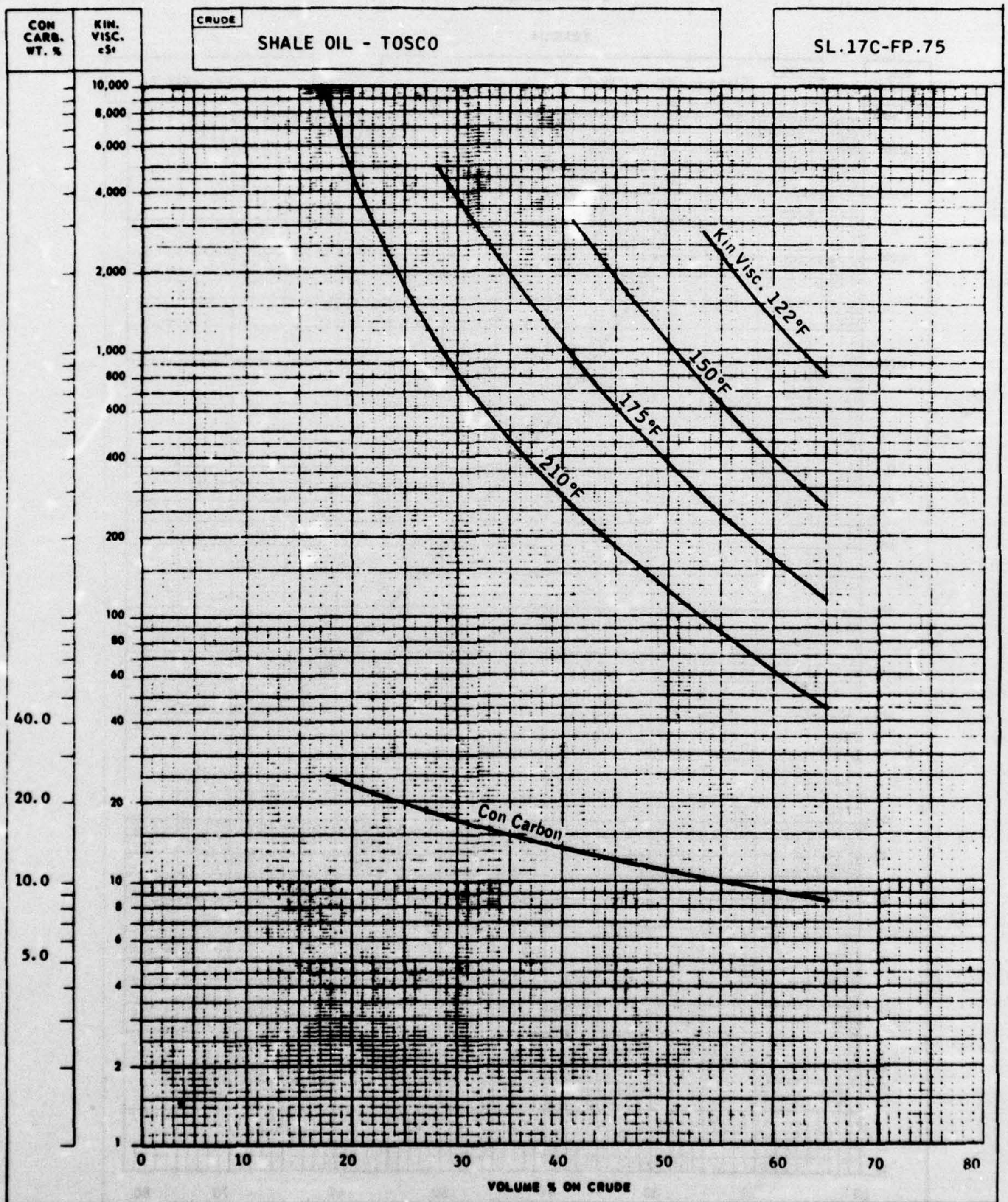
GRAPH NO. 8

RESIDUA



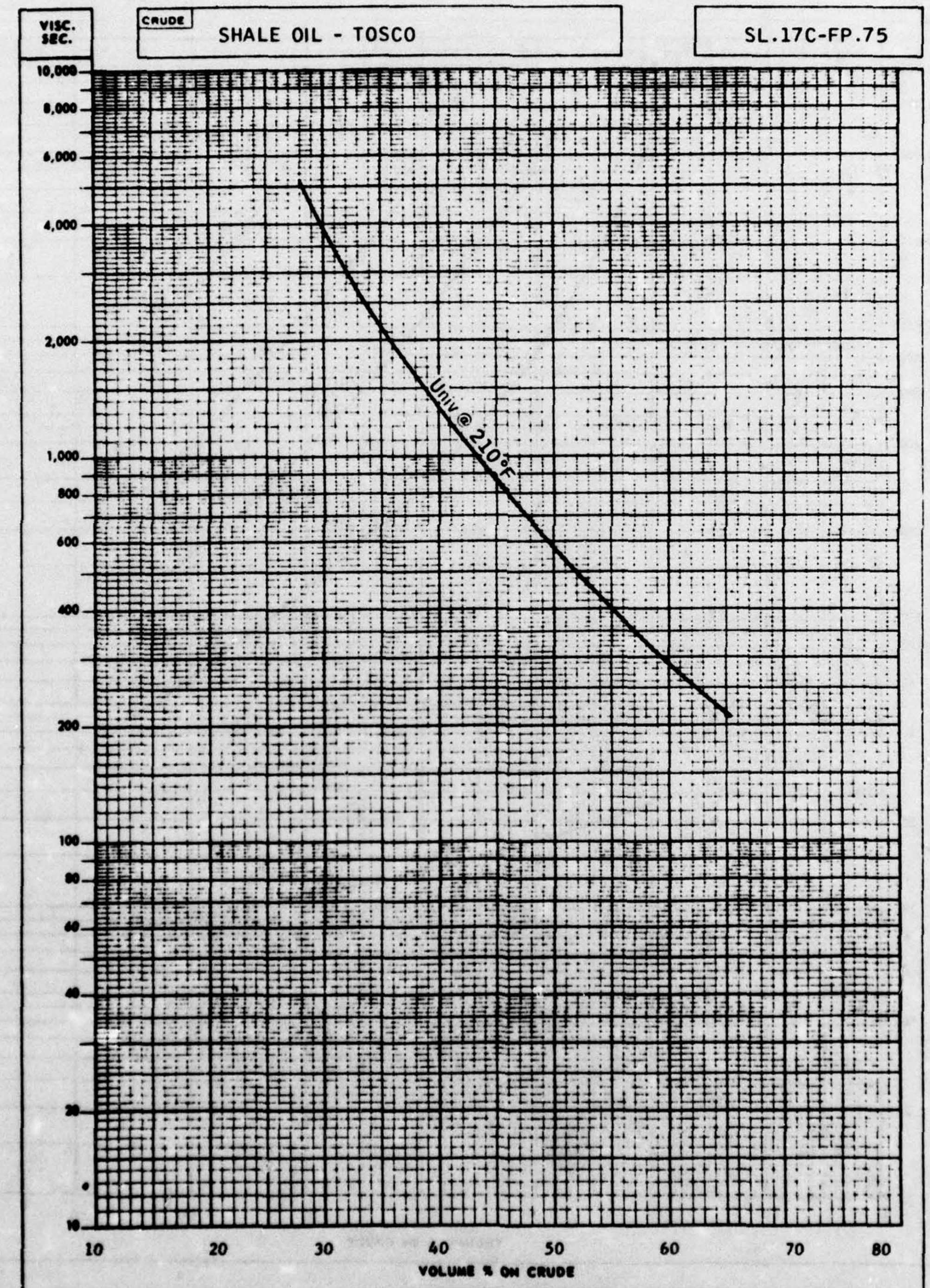
GRAPH NO. 9

RESIDUA



GRAPH NO. 10

RESIDUA



APPENDIX VII

CRUDE ASSAY - GARRETT SHALE OIL

CRUDE:	**SYNCRUDE - GARRETT**
COUNTRY:	COLORADO, U.S.A.
REPRESENTATIVE OF:	Oil extracted from shale rock by in-situ retorting process by Garrett Research and Development Company.

FILE NO.:	SL. 19C-FP. 75
REPORT DATE:	October 1975
REPORT BY:	Gary N. Williams — EXXON RESEARCH & ENGINEERING CO. ENGINEERING INFORMATION CENTER FLORHAM PARK, N.J.

DATE RECEIVED:	3-4-75
DATE DISTILLED:	6-5-75
LAB ASSAY NO.:	2035
COST CENTER:	2524-702 (5800-712160)
CARD NOS.:	

ASSAY RUN BY:

EXXON COMPANY, U.S.A.
REFINING DEPARTMENT
REFINERY LABORATORY
BAYTOWN, TEXAS

SPONSORED BY:

TABLE 1

CRUDE	
SYNCRUDE - GARRETT	SL. 19C-FP. 75

WHOLE CRUDE DATA

GRAVITY		°API	25.0
SPECIFIC GRAVITY		60/60	0.9042
SULFUR		WT. %	0.64
MERCAPTAN SULFUR		WT. PPM	39
POUR POINT		°F	50
NITROGEN		WT. %	1.30
WATER AND SEDIMENT		VOL. %	2.0
SALT CONTENT, NaCl		PTB	1.0
REID VAPOR PRESSURE		PSI	0.2
H_2S (DISSOLVED)		WT. PPM	
NEUT. NO. (D664)		mg KOH/gm	1.53
VISCOSITIES:	KINEMATIC @	122°F, cSt	9.93
		100°F, cSt	15.8
		80°F, cSt	27.0
		60°F, cSt	
		40°F, cSt	
	SAYBOLT UNIVERSAL @	122°F, SEC	58.6
		100°F, SEC	80.1
		80°F, SEC	128
		60°F, SEC	
		40°F, SEC	

LIGHT HYDROCARBONS

% ON CRUDE	WEIGHT	VOLUME
ETHANE AND LIGHTER		
PROPANE		
ISO BUTANE		
NORMAL BUTANE		
ISO PENTANE		
NORMAL PENTANE		

TABLE 2

SYNCRUDE GARRETT   DATA INPUT AND CALCULATIONS   25.0 DEG API   SL.19C-FP.75

TEMPERATURE DEG F		TEMPERATURE DEG C	NORM. VOL. PCT ON CRUDE	NORM. VOL. PCT CUM	NORM. VOL. PCT MID	GRAVITY DEG API	GRAVITY SPECIFIC	SUM OF SPEC GRAV X VOL PCT	RI AT 67 DEG C	DEG F AN. PT.	SUM OF VOL PCT X AN. PT.
	C_2		0.0	0.0	0.0	0.0	1.0760	0.0			
	C_3		0.0	0.0	0.0	0.0	1.0760	0.0			
	iC_4		0.0	0.0	0.0	0.0	1.0760	0.0			
68	nC_4	20.0	0.0	0.0	0.0	0.0	1.0760	0.0			
	iC_5		0.0	0.0	0.0	0.0	1.0760	0.0			
	nC_5		0.0	0.0	0.0	0.0	1.0760	0.0			
158		70.0	0.0	0.0	0.0	0.0	1.0760	0.0			
185		85.0	0.0	0.0	0.0	0.0	1.0760	0.0			
212		100.0	0.0	0.0	0.0	0.0	1.0760	0.0			
248		120.0	0.0	0.0	0.0	0.0	1.0760	0.0			
275		135.0	0.50	0.50	0.25	45.6	0.7990	0.39949			
302		150.0	0.50	1.00	0.75	39.4	0.8280	0.81348			
320		160.0	0.50	1.50	1.25	40.5	0.8227	1.22481	1.4400	50	25.0
347		175.0	0.70	2.20	1.85	42.7	0.8123	1.79341	1.4330	70	74.0
374		190.0	1.10	3.30	2.75	41.2	0.8193	2.69469	1.4342	89	171.9
401		205.0	1.40	4.70	4.00	39.8	0.8260	3.85114	1.4387	100	311.9
428		220.0	1.80	6.50	5.60	38.7	0.8314	5.34761	1.4427	106	502.7
455		235.0	2.10	8.60	7.55	37.4	0.8378	7.10694	1.4460	108	729.5
482		250.0	3.40	12.00	10.30	35.4	0.8478	9.98950	1.4510	109	1100.1
509		265.0	5.00	17.00	14.50	33.2	0.8591	14.28519	1.4595	107	1635.1
536		280.0	5.00	22.00	19.50	31.2	0.8697	18.63367	1.4665	106	2165.1
563		295.0	5.20	27.20	24.60	29.2	0.8805	23.21237	1.4732	114	2757.9
590		310.0	5.80	33.00	30.10	29.9	0.8772	28.30040	1.4712	122	3465.5
617		325.0	6.00	39.00	36.00	29.6	0.8783	33.57040	1.4718	123	4203.5
650		343.3	6.80	45.80	42.40	27.3	0.8911	39.62959	1.4792	123	5039.9
671		355.0	4.40	50.20	48.00	24.8	0.9053	43.61295	1.4885	124	5585.5
698		370.0	5.80	56.00	53.10	24.0	0.9100	48.89075	1.4921	126	6316.3
725		385.0	5.40	61.40	58.70	23.6	0.9123	53.81723	1.4935	129	7012.9
752		400.0	5.20	66.60	64.00	23.1	0.9153	58.57661	1.4943	132	7699.3
779		415.0	5.40	72.00	69.30	22.7	0.9176	63.53186	1.4955	139	8449.9
806		430.0	5.00	77.00	74.50	22.5	0.9188	68.12601	1.4969	145	9174.9
833		445.0	4.30	81.30	79.15	22.2	0.9206	72.08469	1.4987	146	9802.7
851		455.0	2.90	84.20	82.75	21.0	0.9279	74.77550	1.5017	145	10223.2
887		475.0	4.80	89.00	86.60	20.3	0.9321	79.24980	1.5065	141	10900.0
914		490.0	2.20	91.20	90.10	19.3	0.9383	81.31412	1.5155	133	11192.6
950		510.0	1.50	92.70	91.95	15.9	0.9600	82.75407	1.5228	126	11381.6
968		520.0	0.30	93.20	92.95	14.6	0.9685	83.23833	1.5290	118	11440.6
995		535.0	0.90	94.10	93.65	13.5	0.9759	84.11661	1.5355	116	11545.0
1022		550.0	0.70	94.80	94.45	12.5	0.9826	84.80444	1.5400	114	11624.8
1049		565.0	0.70	95.50	95.15	11.2	0.9916	85.49855	1.5490	114	11704.6
1049+		565.0+	4.50	100.00	97.75	2.1	1.0591	90.26463			

TABLE 3

SYNCRUDE GARRETT DAT. INPUT AND CALCULATIONS 25.0 DEG API SL.19C-FP.75

TEMPERATURE DEG F	DEG C	CALC WT PCT ON CRUDE	NORM WT PCT ON CRUDE	CUM	MID	SUM WT PCT SULFUR X NORM WT PCT	WT PCT SULFUR	WT PCT CON CARBON	SUM WT PCT CON CARBON X NORM WT PCT	WT PCT NITROGEN	SUM WT PCT NITROGEN X NORM WT PCT
C_2		0.0	0.0	0.0	0.0						
C_3		0.0	0.0	0.0	0.0						
iC_4		0.0	0.0	0.0	0.0						
64 nC_4	20.0	0.0	0.0	0.0	0.0	0.0	0.0				
iC_5		0.0	0.0	0.0	0.0	0.0	0.0				
nC_5		0.0	0.0	0.0	0.0	0.0	0.0				
158	70.0	0.0	0.0	0.0	0.0	0.0	0.0				
185	85.0	0.0	0.0	0.0	0.0	0.0	0.0				
212	100.0	0.0	0.0	0.0	0.0	0.0	0.0				
248	120.0	0.0	0.0	0.0	0.0	0.0	0.0				
275	135.0	0.44	0.44	0.44	0.22	0.181	0.4100				
302	150.0	0.46	0.46	0.90	0.67	0.388	0.4500				
320	160.0	0.45	0.46	1.36	1.13	0.629	0.5300				
347	175.0	0.63	0.63	1.99	1.67	1.089	0.7300				
374	190.0	1.00	1.00	2.99	2.49	1.778	0.6900				
401	205.0	1.28	1.28	4.27	3.63	2.790	0.7900				
428	220.0	1.66	1.66	5.92	5.10	3.727	0.5650			0.4300	0.7129
455	235.0	1.95	1.95	7.87	6.90	4.789	0.5450			0.4400	1.5705
482	250.0	3.19	3.19	11.07	9.47	6.450	0.5200			0.4500	3.0075
509	265.0	4.75	4.76	15.83	13.45	9.210	0.5800			0.4800	5.2918
536	280.0	4.81	4.82	20.64	18.23	12.727	0.7300			0.5300	7.8451
563	295.0	5.06	5.07	25.72	23.18	16.227	0.6900			0.6100	10.9394
590	310.0	5.63	5.64	31.35	28.53	19.609	0.6000			0.7600	15.2233
617	325.0	5.83	5.84	37.19	34.27	22.820	0.5500			1.0700	21.4704
650	343.3	6.70	6.71	43.90	40.55	26.646	0.5700			1.5500	31.8751
671	355.0	4.41	4.41	48.32	46.11	29.162	0.5700	0.00	0.0221	1.6000	38.9359
698	370.0	5.84	5.85	54.16	51.24	32.378	0.5500	0.01	0.0688	1.6000	48.2911
725	385.0	5.45	5.46	59.62	56.89	35.243	0.5250	0.01	0.1289	1.6000	57.0237
752	400.0	5.26	5.27	64.89	62.26	37.800	0.4850	0.02	0.2238	1.5900	65.4073
779	415.0	5.48	5.49	70.38	67.64	40.051	0.4100	0.03	0.3995	1.5600	73.9712
806	430.0	5.08	5.09	75.47	72.93	42.138	0.4100	0.06	0.7252	1.5200	81.7074
833	445.0	4.38	4.39	79.86	77.67	43.760	0.3700	0.14	1.3392	1.5200	88.3736
851	455.0	2.98	2.98	82.84	81.35	44.983	0.4100	0.30	2.2335	1.5200	92.9048
887	475.0	4.95	4.96	87.80	85.32	47.089	0.4250	0.73	5.8520	1.5700	
914	490.0	2.28	2.29	90.03	88.94	48.347	0.5500	1.80	9.9685	1.6200	
950	510.0	1.59	1.60	91.68	90.88	49.432	0.6800	3.06	14.8500	1.6900	
968	520.0	0.54	0.54	92.22	91.95	49.818	0.7200	4.14	17.0711	1.7200	
995	535.0	0.97	0.97	93.19	92.70	50.645	0.8500	5.10	22.0334	1.7500	
1022	550.0	0.76	0.76	93.95	93.57	51.369	0.9500	7.00	27.3676	1.8000	
1049	565.0	0.77	0.77	94.72	94.34	52.146	1.0100	8.60	33.9808	1.8300	
1049+	565.0+	5.27	5.28	100.00	97.36	59.115	1.3200	27.20	177.6004	1.9800	
		99.83									

SYNCRUDE GARRETT | CALCULATED BLENDS | 25.0 DEG API | TABLE 4 | SL.19C-FP.75

TEMP. RANGE F		VOLUME% INIT	VOLUME% FINAL	VOLUME YIELD	MID VOLUME	GRAVITY DEG API	GRAVITY SPECIFIC	NORM WT PCT	SULFUR WT PCT	RI AT 67 DEG C	CON CARBON	WT PCT NITROGEN	ANILINE PT
248	302	0.0	1.00	1.00	0.50	42.44	0.8135	0.90	0.4304				
248	374	0.0	3.30	3.30	1.65	41.79	0.8166	2.99	0.5956				
302	374	1.00	3.30	2.30	2.15	41.50	0.8179	2.08	0.6671	1.4351			75
302	401	1.00	4.70	3.70	2.85	40.85	0.8210	3.37	0.7139	1.4365			84
302	455	1.00	8.60	7.60	4.80	39.38	0.8281	6.97	0.6313	1.4406			96
302	509	1.00	17.00	16.00	9.00	36.56	0.8420	14.92	0.5911	1.4487			102
302	536	1.00	22.00	21.00	11.50	35.25	0.8486	19.74	0.6250	1.4529			103
302	698	1.00	56.00	55.00	28.50	30.37	0.8741	53.26	0.6006	1.4691			115
320	650	1.50	45.80	44.30	23.65	31.72	0.8669	42.55	0.6115	1.4644			113
347	698	2.20	56.00	53.80	29.10	30.14	0.8754	52.18	0.5997	1.4698			116
374	482	3.30	12.00	8.70	7.65	37.26	0.8385	8.08	0.5781	1.4461			107
374	536	3.30	22.00	18.70	12.65	34.51	0.8524	17.66	0.6200	1.4551			107
401	509	4.70	17.00	12.30	10.85	35.30	0.8483	11.56	0.5554	1.4524		0.4578	108
401	650	4.70	45.80	41.10	25.25	31.05	0.8705	39.64	0.6019	1.4667		0.8042	115
428	536	6.50	22.00	15.50	14.25	33.58	0.8572	14.72	0.6114	1.4581		0.4846	107
509	590	17.00	33.00	16.00	25.00	30.04	0.8760	15.53	0.6697	1.4704		0.6396	114
536	650	22.00	45.80	23.80	33.90	28.90	0.8822	23.26	0.5984	1.4741		1.0331	121
590	650	33.00	45.80	12.80	39.40	28.37	0.8851	12.55	0.5607	1.4757		1.3267	123
590	698	33.00	56.00	23.00	44.50	26.56	0.8952	22.81	0.5598	1.4823		1.4496	124
650	752	45.80	66.60	20.80	56.20	23.84	0.9109	20.99	0.5314	1.4923	0.01	1.5975	128
650	851	45.80	84.20	38.40	65.00	23.10	0.9153	38.94	0.4709	1.4947	0.06	1.5674	135
650	1049	45.80	95.50	49.70	70.65	21.82	0.9229	50.82	0.5018	1.5001	0.67	1.5864	134
752	851	66.60	84.20	17.60	75.40	22.24	0.9204	17.95	0.4002	1.4977	0.11	1.5322	143
779	995	72.00	94.10	22.10	83.05	20.42	0.9314	22.80	0.4646	1.5059	0.95	1.5673	140
851	950	84.20	92.70	8.50	88.45	19.25	0.9387	8.84	0.5034	1.5117	1.43	1.6046	136
851	1049	84.20	95.50	11.30	89.85	17.61	0.9489	11.88	0.6030	1.5184	2.67	1.6488	131
950	1049	92.70	95.50	2.80	94.10	12.86	0.9802	3.04	0.8926	1.5388	6.29	1.7775	115
995	1049	94.10	95.50	1.40	94.80	11.85	0.9871	1.53	0.9801	1.5445	7.80	1.8151	114

RESIDUE

DEG F TEMP	YLD% VOLUME	GRAVITY DEG API	GRAVITY SPECIFIC	YLD WT PCT	WT% SULFUR	WT% CON CARBON	WT% NITROGEN
1049+	4.50	2.1	1.0591	5.28	1.32	27.20	1.98
995+	5.90	4.3	1.0420	6.81	1.24	22.84	1.94
950+	7.30	6.0	1.0288	8.32	1.16	19.56	1.91
851+	15.80	12.8	0.9803	17.16	0.82	10.22	1.75
752+	33.40	17.6	0.9487	35.11	0.61	5.05	1.64
698+	44.00	19.0	0.9403	45.84	0.58	3.87	1.63
650+	54.20	20.0	0.9342	56.10	0.58	3.17	1.62
563+	72.80	22.1	0.9210	74.28	0.58	2.39	1.51
428+	93.50	24.3	0.9082	94.08	0.59	1.99	1.30

TABLE 5

CRUDE	
SYNCRUDE - GARRETT	SL. 19C-FP. 75

GASOLINES & NAPHTHAS

15/5 CUT POINT	°F VT	68/158	68/212	158/212	248/302	248/374	302/374
15/5 CUT POINT	°C VT	20/70	20/100	70/100	120/150	120/190	150/190
YIELD CUT RANGE	VOL. %				0.0-1.0	0.0-3.3	1.0-3.3
YIELD ON CRUDE	VOL. %				1.0	3.3	2.3
MID-POINT	VOL. %				0.5	1.6	2.2
GRAVITY	°API				42.4	41.8	41.5
SPECIFIC GRAVITY	60/60				0.8137	0.8165	0.8179
TOTAL SULFUR	WT. %				0.43	0.60	0.67
MERCAPTAN SULFUR	WT. PPM				272	120	75
REID VAPOR PRESSURE	PSI						
RESEARCH OCTANE NUMBER							
CLEAR							
+ 1.5 ml TEL/USG							
+ 3.0 ml TEL/USG							
MOTOR OCTANE NUMBER							
CLEAR							
+ 1.5 ml TEL/USG							
+ 3.0 ml TEL/USG							
VOL. % D + L @ 70°C/158°F							
@ 100°C/212°F							
FBP	°F						
ANILINE POINT, °F							75
		GC		GC	GC / HC		HC
PARAFFINS	VOL. %						39.0
NAPHTHENES	VOL. %						31.7
AROMATICS	VOL. %						29.3

TABLE 6

CRUDE: SYNCRUDE - GARRETT

SL. 19C-FP. 75

KEROSENE & TURBO FUELS

15/5 CUT POINT	°F VT	302-401	302-455	302-509	374-482	374-536
15/5 CUT POINT	°C VT	150-205	150-235	150-265	190-250	190-280
YIELD CUT RANGE	VOL. %	1.0-4.7	1.0-8.6	1.0-17.0	3.3-12.0	3.3-22.0
YIELD ON CRUDE	VOL. %	3.7	7.6	16.0	8.7	18.7
MID-POINT	VOL. %	2.8	4.8	9.0	7.6	12.6
GRAVITY	°API	40.9	39.4	36.6	37.3	34.5
SPECIFIC GRAVITY	60/60	0.8208	0.8280	0.8418	0.8383	0.8524
TOTAL SULFUR	WT. %	0.71	0.63	0.59	0.58	0.62
MERCAPTAN SULFUR	WT. PPM	50	82			
SMOKE POINT	MM	16	15	14	15	13
LUM. NO.		37.0	35.5	32.0	33.0	28.0
FREEZING POINT	°F	Too Dark				
CLOUD POINT	°F	Too Dark				
POUR POINT	°F	-85	-65	-45	-50	-35
ANILINE POINT	°F	84	96	102	107	107
DIESEL INDEX		34	38	37	40	37
COLOR	SAYBOLT					
REFRACTIVE INDEX @ 67°C		1.4365	1.4406	1.4487	1.4461	1.4551
AROMATICS, FIA	VOL. %	Too Dark				
VISCOSITIES:						
KINEMATIC @ -30°F	cSt	5.57	9.40	25.5	18.8	34.0
@ 100°F	cSt	1.11	1.39	2.05	1.81	2.27
@ 210°F	cSt	0.59	0.69	0.90	0.82	0.96

TABLE 7

CRUDE	SYNCRUDE - GARRETT	SL. 19C-FP. 75

MIDDLE DISTILLATES

15.5 CUT POINT	F VT	401-509	509-590	590-650	590-698	320-650	401-650	302-698	
15-5 CUT POINT	C VT	205-265	265-310	310-343	310-370	160-343	205-343	150-370	
YIELD CUT RANGE	VOL. %	4.7-17.0	17.0-33.0	33.0-45.8	33.0-56.0	1.5-45.8	4.7-45.8	1.0-56.0	
YIELD ON CRUDE	VOL. %	12.3	16.0	12.8	23.0	44.3	41.1	55.0	
MID-POINT	VOL. %	10.8	25.0	39.4	44.5	23.6	25.2	28.5	
GRAVITY	API	35.3	30.0	28.4	26.6	31.7	31.0	30.4	
SPECIFIC GRAVITY	60 60	0.8483	0.8762	0.8849	0.8950	0.8670	0.8708	0.8740	
TOTAL SULFUR	WT. %	0.56	0.67	0.56	0.56	0.61	0.60	0.60	
ANILINE POINT	F	108	114	123	124	113	115	115	
DIESEL INDEX		38	34	35	33	36	35	35	
CETANE INDEX		42	45	48	50	46	46	47	
CLOUD POINT	F	Too Dark							
POUR POINT	F	-40	0	35	50	-5	10	25	
REFRACTIVE INDEX @ 67°C		1.4531	1.4704	1.4757	1.4823	1.4644	1.4667	1.4691	
NEUT. NO. (D-974)	mg KOH/gm	2.04	2.04	2.04					
VISCOSITIES:									
KINEMATIC @ 100°F	cSt	2.15	3.97	7.65	9.92	3.53	3.90	4.15	
@ 130°F	cSt	1.37	2.23	3.70	4.50	2.01	2.18	2.37	
@ 175°F	cSt								
@ 210°F	cSt	0.92	1.33	1.97	2.31	1.27	1.34	1.43	
A.R.		11.0	13.7	13.2					
N.R.		34.8	37.1	35.6					
NITROGEN	Wt. %	0.46	0.64	1.33	1.45		0.80		

TABLE 8

CRUDE

SYNCRUDE - GARRETT

SL. 19C-FP. 75

GAS OILS

15/5 CUT POINT	°F VT	650-752	752-851	851-950	950-1049	650-851	650-1049	851-1049	995-1049
15/5 CUT POINT	°C VT	343-400	400-455	455-510	510-565	343-455	343-565	455-565	535-565
YIELD CUT RANGE	VOL. %	45.8-66.6	66.6-84.2	84.2-92.7	92.7-95.5	45.8-84.2	45.8-95.5	84.2-95.5	94.1-95.5
YIELD ON CRUDE	VOL. %	20.8	17.6	8.5	2.8	38.4	49.7	11.3	1.4
MID-POINT	VOL. %	56.2	75.4	88.4	94.1	65.0	70.6	89.8	94.8
GRAVITY	API	23.8	22.2	19.2	12.9	23.1	21.8	17.6	11.8
SPECIFIC GRAVITY	60/60	0.9111	0.9206	0.9390	0.9799	0.9153	0.9230	0.9490	0.9874
TOTAL SULFUR	WT. %	0.53	0.40	0.50	0.89	0.47	0.50	0.60	0.98
ANILINE POINT	°F	128	143	136	115	135	134	131	114
CON CARBON	WT. %	0.01	0.11	1.43	6.29	0.06	0.67	2.67	7.80
POUR POINT	°F	70	100	110	115	85	90	110	115
REFRACTIVE INDEX 67°C		1.4923	1.4977	1.5117	1.5388	1.4947	1.5001	1.5184	1.5445
NEUT. NO.	mg KOH/gm	0.43							
NITROGEN	WT. %	1.60	1.53	1.60	1.78	1.57	1.59	1.65	1.82
VISCOSITIES									
KINEMATIC 100°F	cSt	19.0							
@ 150°F	cSt	7.18	21.0	90.0	1000	11.3	18.0	150	2004
@ 175°F	cSt								
@ 210°F	cSt	3.33	7.37	21.1	116	4.73	6.65	30.5	184
BASIC NITROGEN	WT. %					0.69		0.93	
OXYGEN	WT. %					0.61		0.81	
METALS									
VANADIUM	WT. PPM							0.1	
NICKEL	WT. PPM							3.3	
IRON	WT. PPM							14.4	
A.R.		15.9	14.8	17.3	23.3				25.0
N.R.		40.2	39.3	43.3	57.5				60.1

TABLE 9

CRUDE	
SYNCRUDE - GARRETT	SL. 19C-FP. 75

LUBE DISTILLATES

		WAXY LUBE	DEWAXED LUBE
15/5 CUT POINT	°F VT	779-995	
15/5 CUT POINT	°C VT	415-535	
YIELD CUT RANGE	VOL. %	70.8-94.1	
YIELD ON CRUDE	VOL. %	23.3	
MID-POINT	VOL. %	82.4	
GRAVITY	°API	20.6	
SPECIFIC GRAVITY	60/60	0.9303	
TOTAL SULFUR	WT. %	0.47	
CON CARBON	WT. %	0.89	
ANILINE POINT	°F	141	
REFRACTIVE INDEX @ 67°C		1.5048	
NEUT. NO. (D-974)	mg KOH/gm	0.76	
NITROGEN	WT. %	1.67	
POUR POINT	°F	105	
WAX CONTENT	WT. %	12.0	
WAX MELTING POINT	°F		
VISCOSITY INDEX		32	
VISCOSITIES:			
KINEMATIC @ 100°F	cSt	(201)	
@ 150°F	cSt	42.7	
@ 175°F	cSt		
@ 210°F	cSt	12.42	
SAYBOLT UNIVERSAL @ 100°F	SEC	(931)	
@ 210°F	SEC	68.0	

PHENOL TREATING SUSCEPTIBILITY*	
PHENOL TREATING CHARACTERISTICS OF DEWAXED LUBE CUT	
PHENOL/OIL RATIO	
Treat	VI
RAW STOCK	
1/1	
2/1	
3/1	
VISCOSITY GRAVITY CONSTANT	

*From Established Correlations

Yields on this table are those as cut from still and the inspections are raw data, not corrected

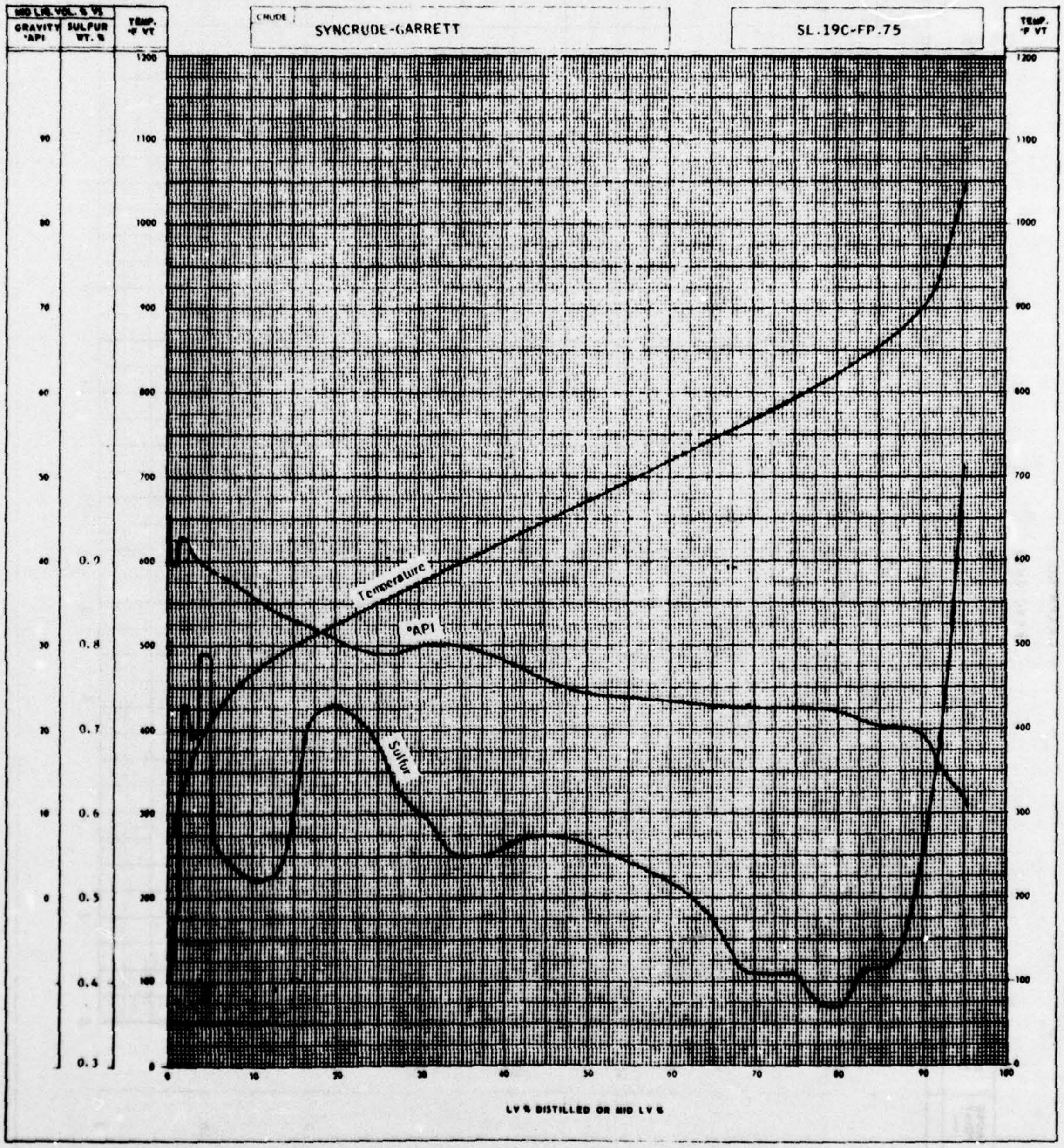
TABLE 10

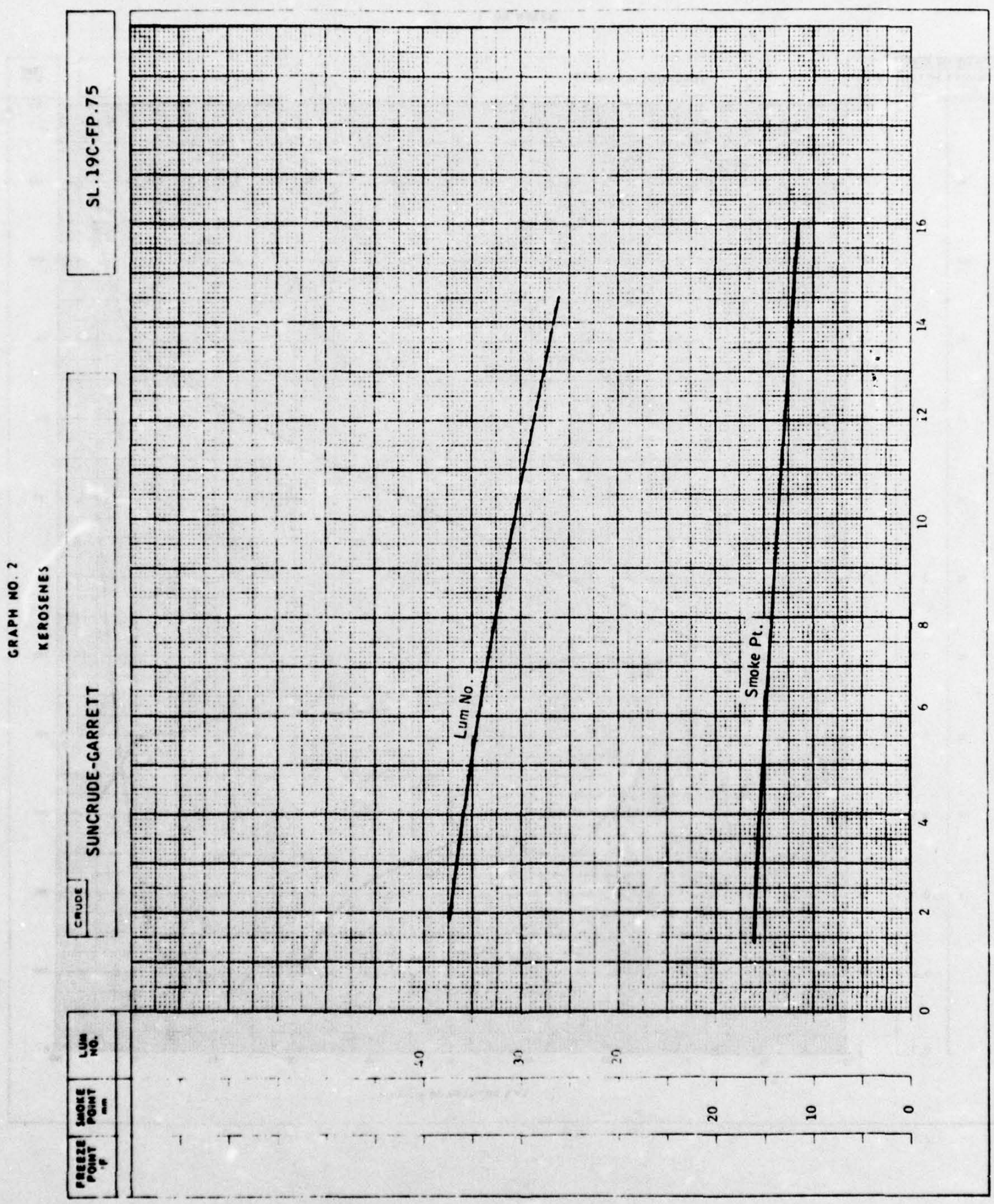
CRUDE: SYNCRUDE - GARRETT | SL. 19C-FP. 75

RESIDUA

15/5 CUT POINT	°F VT	650+	698+	752+	851+	950+	995+	1049+	
15/5 CUT POINT	°C FT	343+	370+	400+	455+	510+	535+	565+	
YIELD ON CRUDE	VOL. %	54.2	44.0	33.4	15.8	7.3	5.9	4.5	
GRAVITY	°API	20.0	19.0	17.6	12.8	6.0	4.3	2.1	
SPECIFIC GRAVITY	60/60	0.9340	0.9402	0.9490	0.9806	1.0291	1.0420	1.0591	
TOTAL SULFUR	WT. %	0.58	0.58	0.61	0.82	1.16	1.24	1.32	
CON CARBON	WT. %	3.2	3.9	5.0	10.2	19.6	22.8	27.2	
NITROGEN	WT. %	1.62	1.63	1.64	1.75	1.91	1.94	1.98	
NEUT NO. (D-664)	mg KOH/gm	0.48							
POUR POINT	°F	90	95	100	115	>120	>120	>120	
VISCOSITIES									
KINEMATIC @ 100°F	cSt	140	280	(660)					
@ 122°F	cSt	68.2	127	271					
@ 150°F	cSt	33.2	56.0	107	1699				
@ 175°F	cSt	19.1	30.5	55.0	580				
@ 210°F	cSt	10.5	15.4	26.2	186	12394	(86,826)		
FUROL @ 275°F	SEC								
@ 350°F	SEC							985	
UNIVERSAL @ 210°F	SEC	61.0	79.5	125.5	867				
REDWOOD 1 @ 100°F	SEC	571	1142	(2691)					
ABSOLUTE VISC. @ 140°F	POISES								
METALS:									
VANADIUM	WT. PPM	1.2			3.9			12.7	
NICKEL	WT. PPM	6.1			19.8			57.2	
IRON	WT. PPM	60.0			196			605	
[illegible]	WT. %								
[illegible]	WT. %								
OXYGEN	WT. %	0.80						1.29	

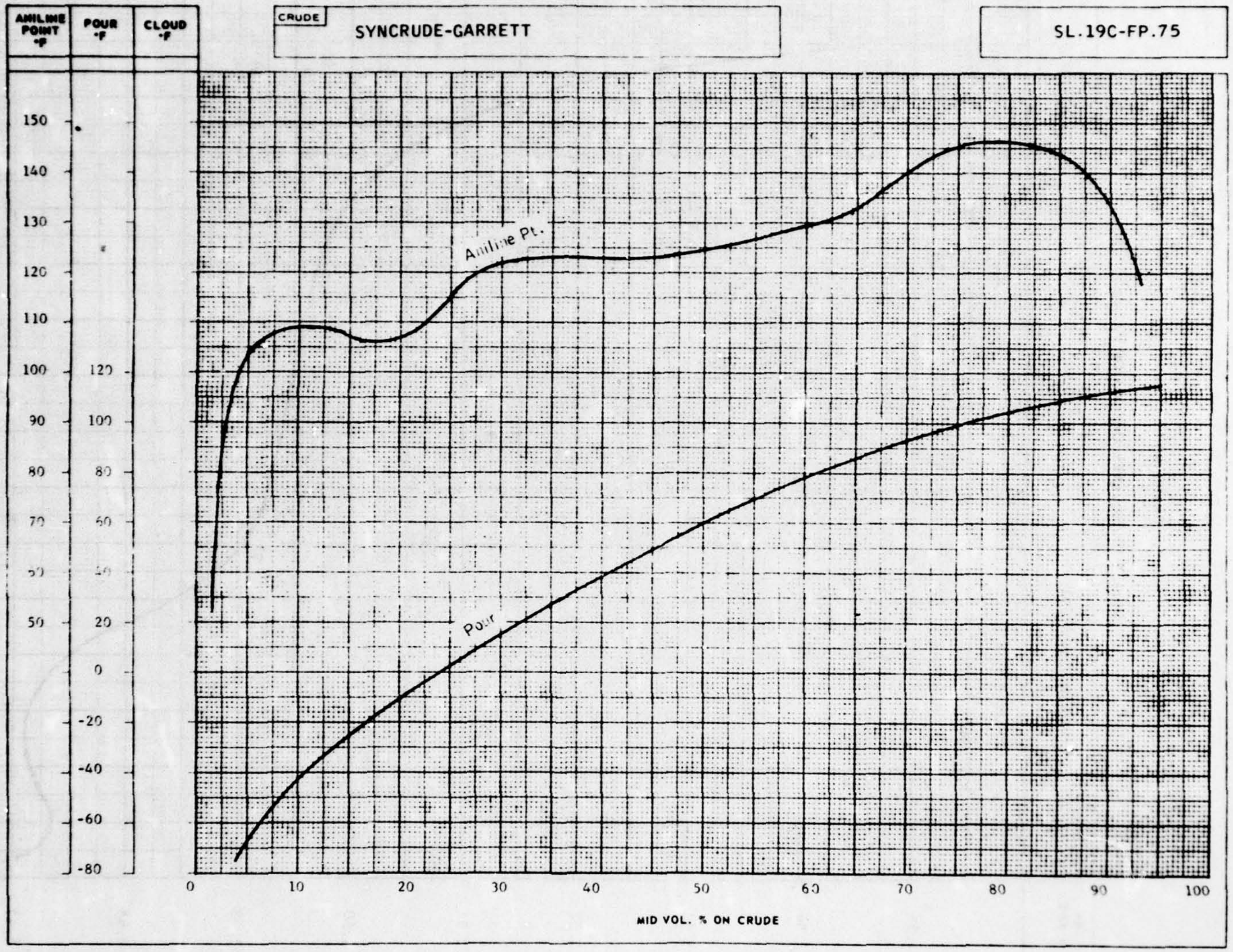
GRAPH NO. 1


MID LIQ. VOL. % VS
GRAVITY °API
SULFUR WT. %
TEMP. °F VT
CRUDE
SYNCRUDE-GARRETT
SL.19C-FP.75
Temperature
°API
Sulfur
LV % DISTILLED OR MID LV %
GRAPH 1


GRAPH 3
GRAPH NO. 2
KEROSENES
CRUDE
SUNCRUDE-GARRETT
SL.19C-FP.75
Lum No.
Smoke Pt.
FREEZE POINT °F
SMOKE POINT mm
LUM NO.
0
2
4
6
8
10
12
14
16
40
30
20
20
10
0

GRAPH NO. 3

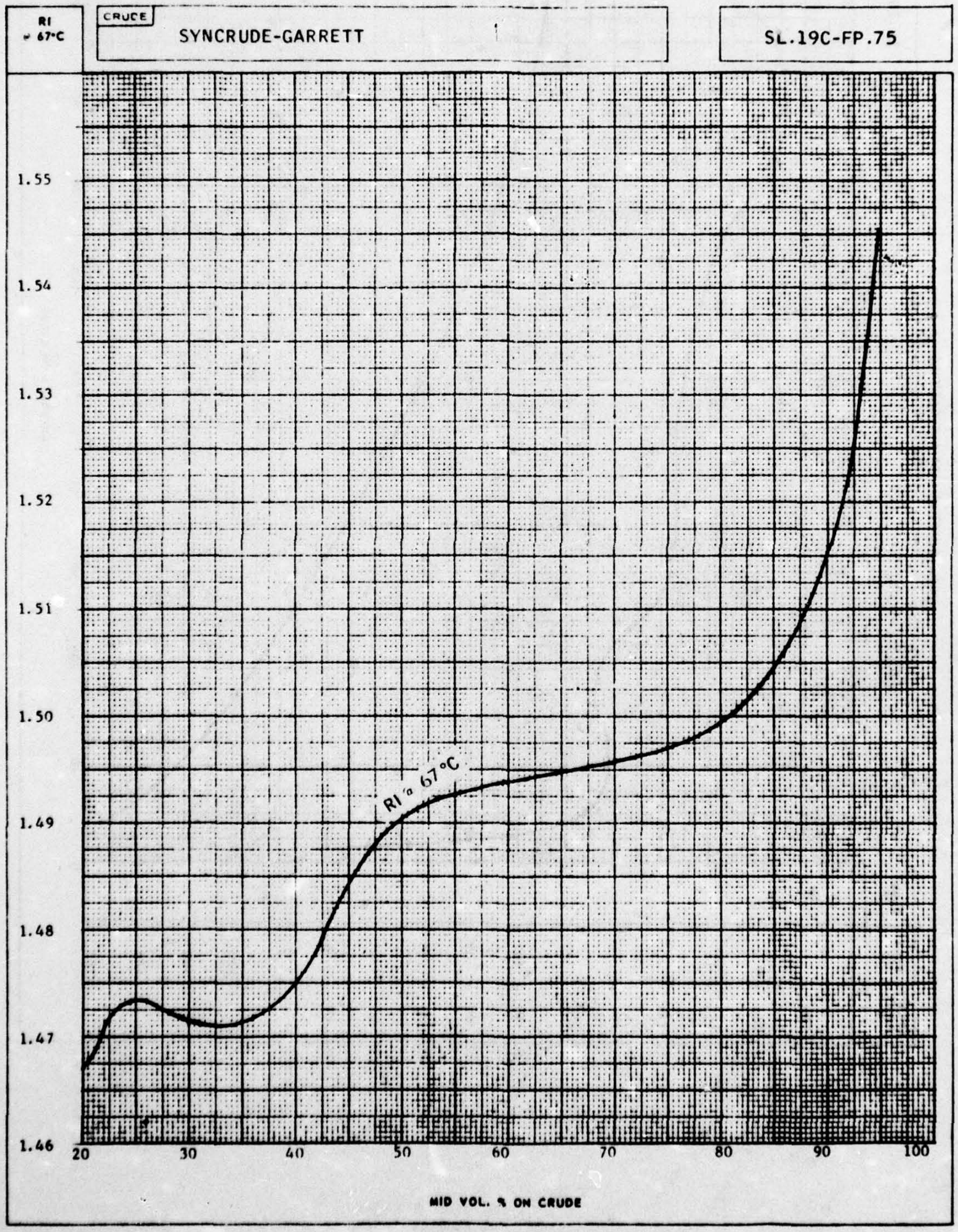
MIDDLE DISTILLATES AND GAS OILS



GRAPH 3

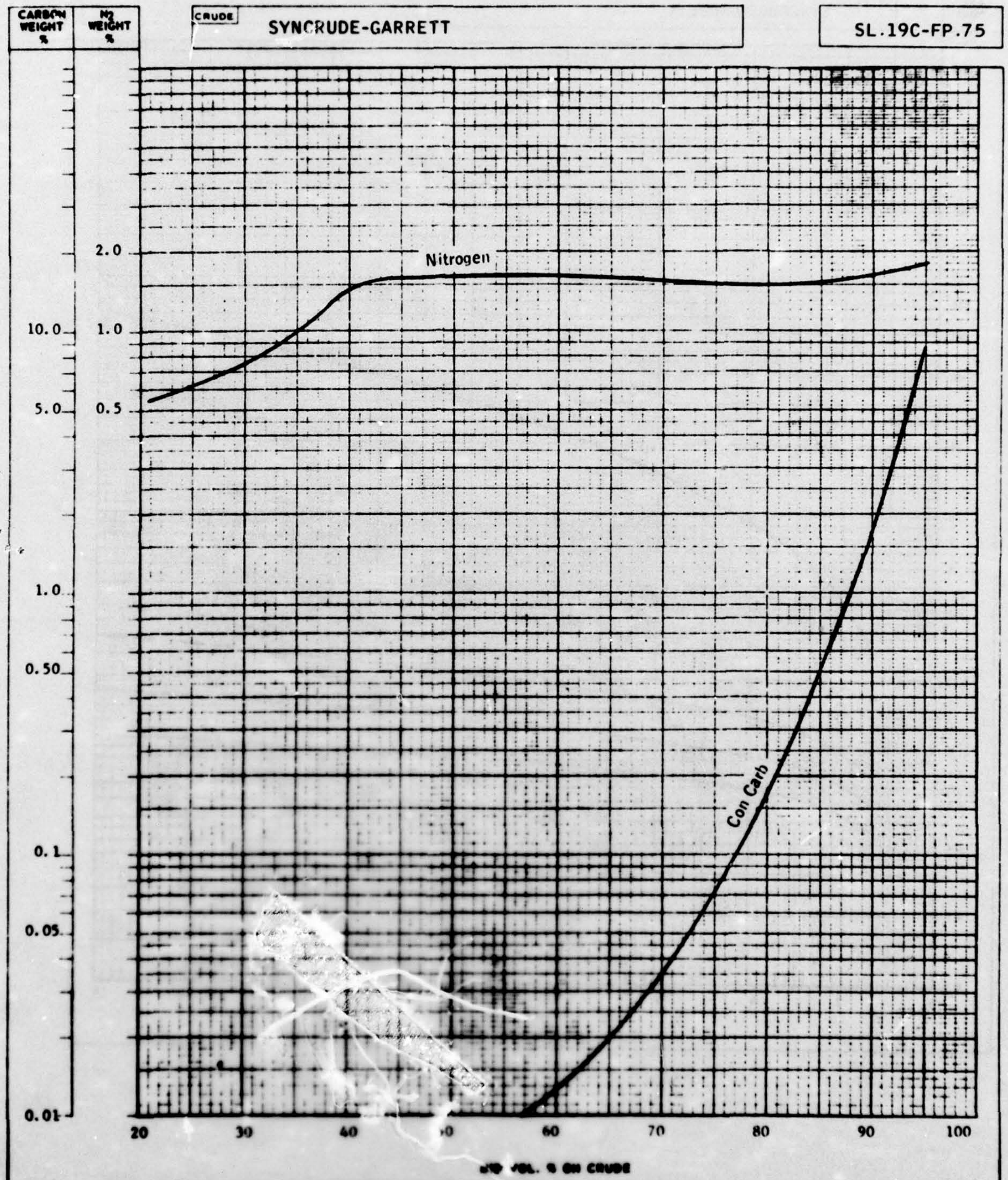
GRAPH NO. 4

MIDDLE DISTILLATES AND GAS OILS



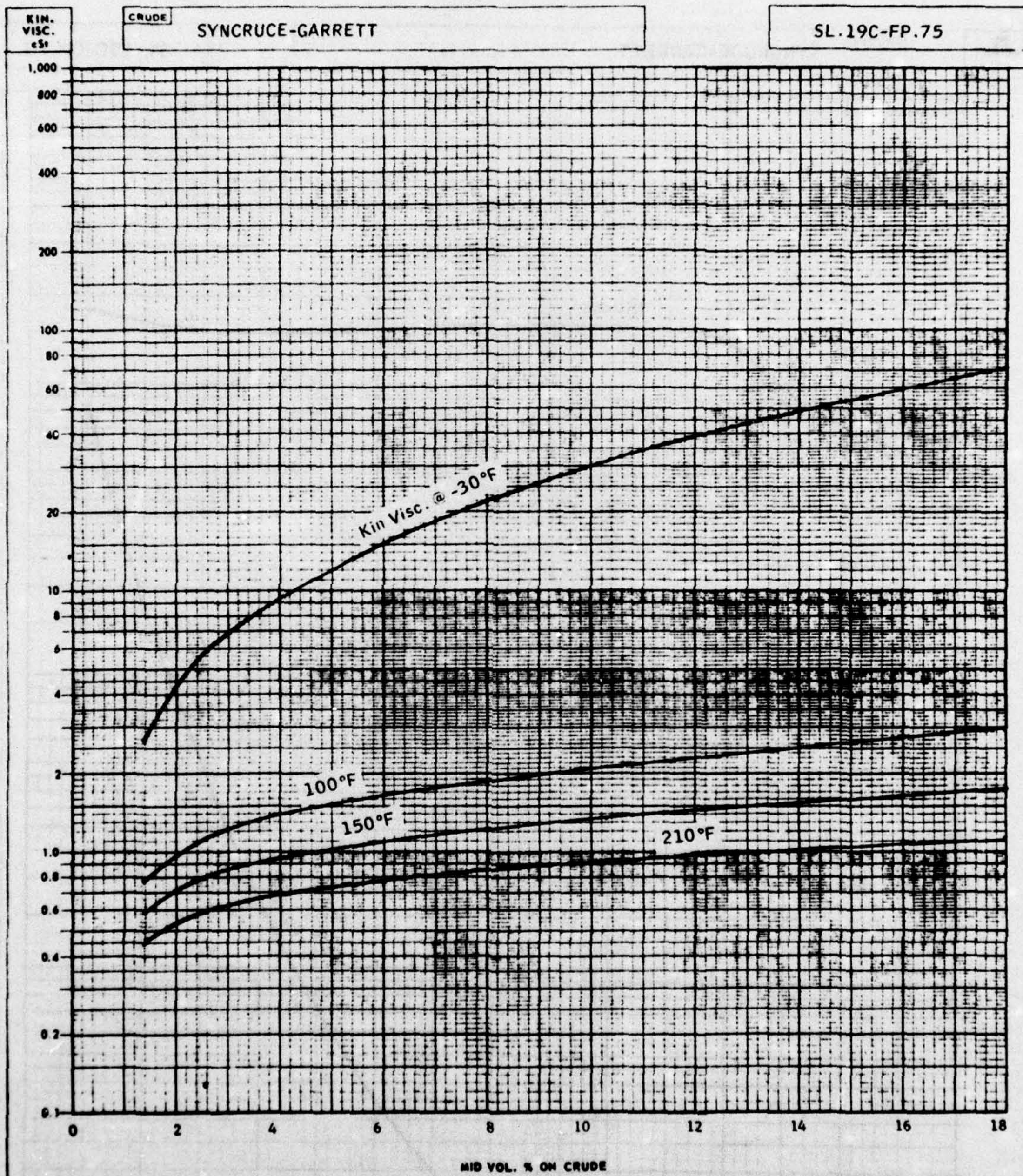
GRAPH. NO. 5

MIDDLE DISTILLATES AND GAS OILS



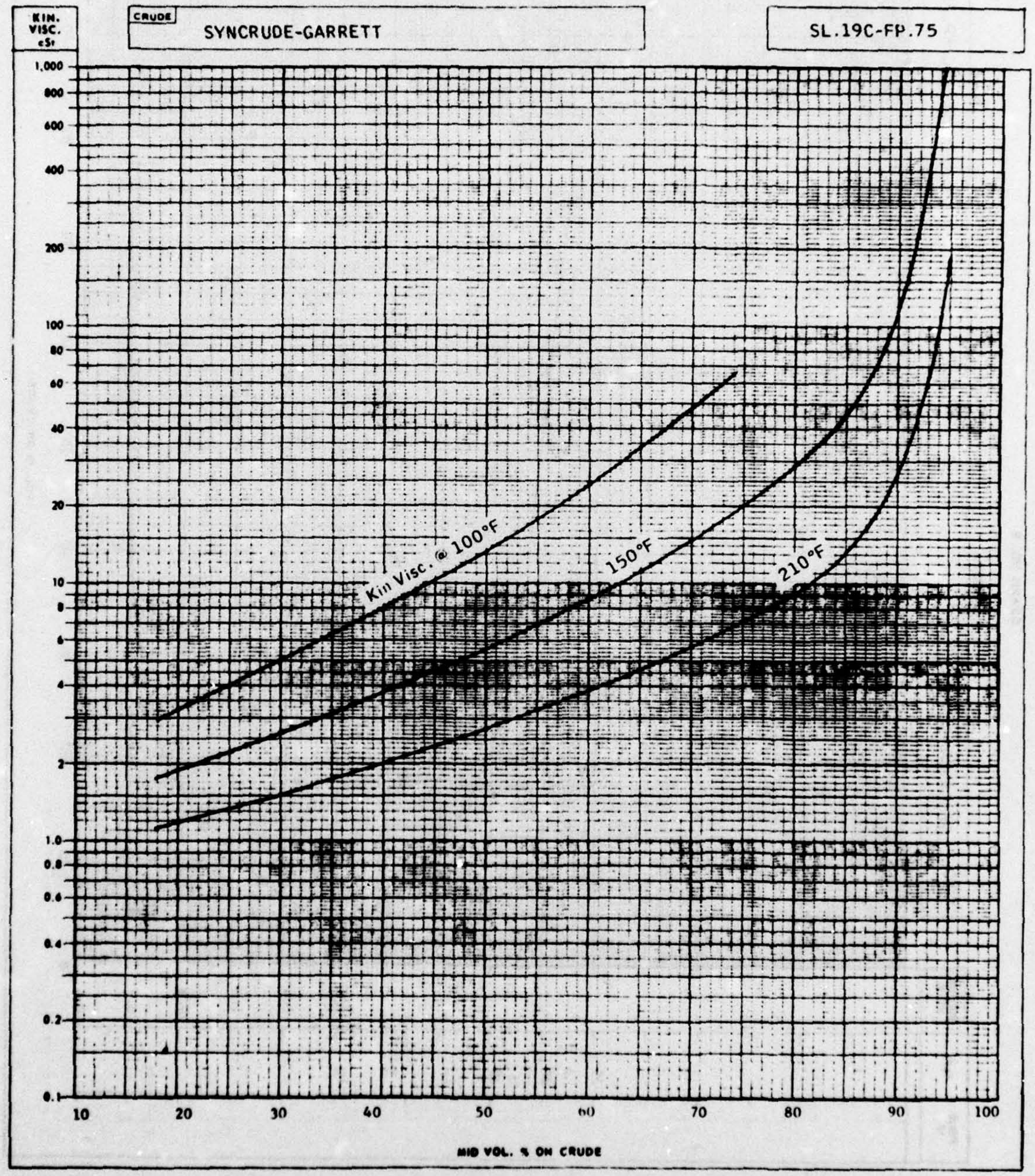
GRAPH NO. 6

MIDDLE DISTILLATES AND GAS OILS



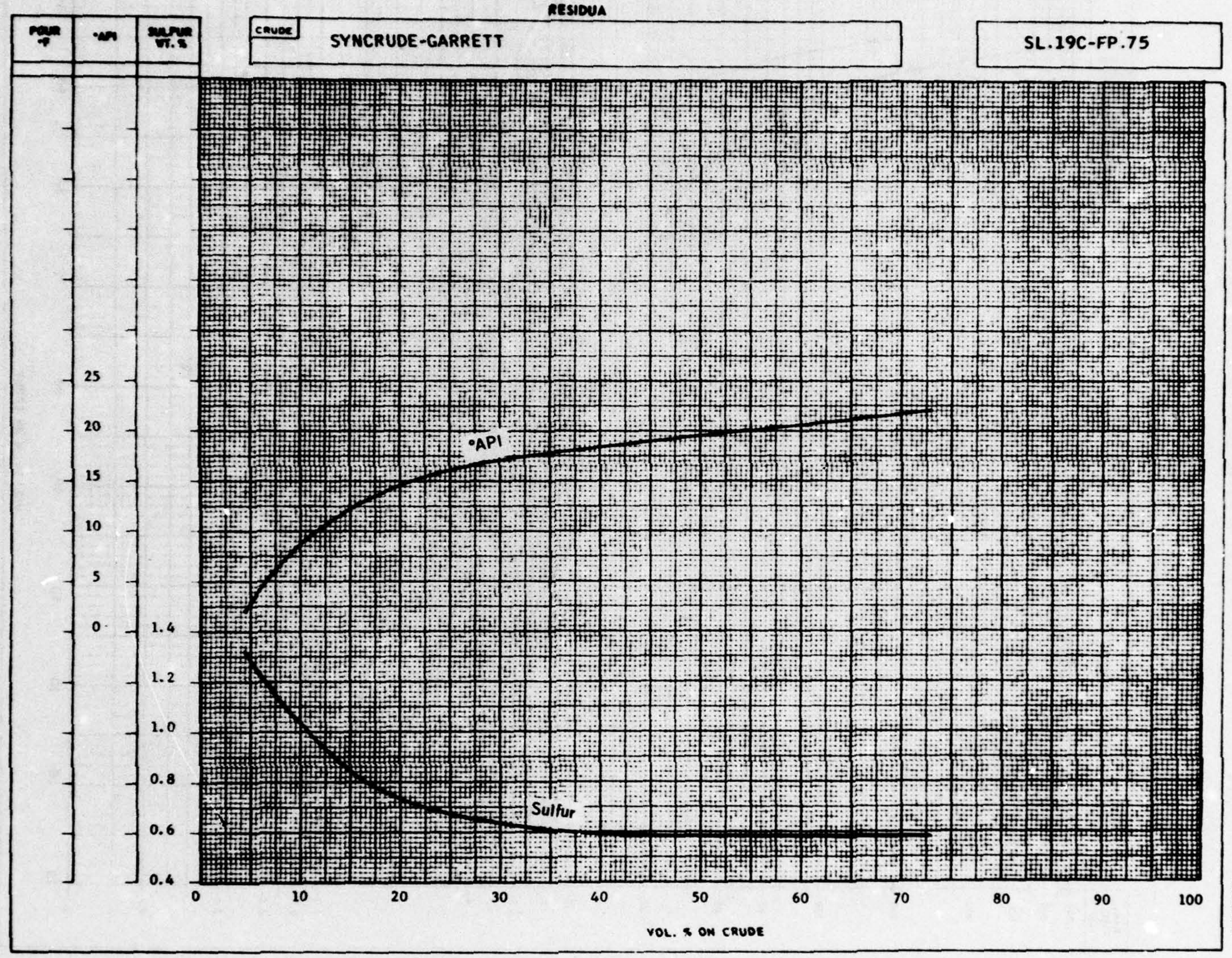
GRAPH NO. 7

MIDDLE DISTILLATES AND GAS OILS



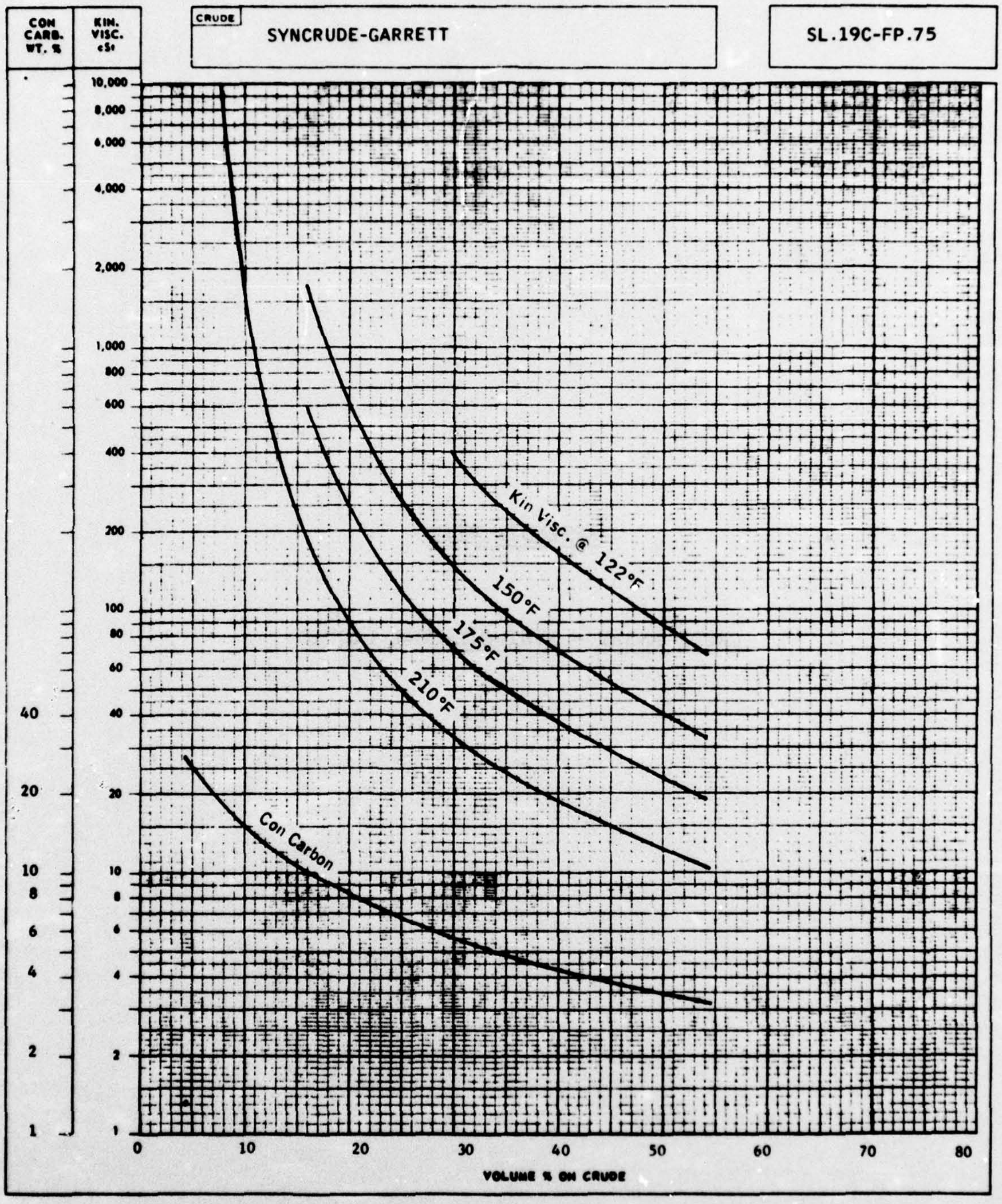
GRAPH NO. 8

RESIDUA



GRAPH NO. 9

RESIDUA



APPENDIX VIII

CRUDE ASSAY - SYNTHOIL COAL LIQUID

CRUDE:	SYNTHOIL
LOCATION:	Bruceton, Pennsylvania
REPRESENTATIVE OF:	Pilot plant sample produced by the SYNTHOIL process of the U.S.B.M., at the Pittsburg Energy Research Center

FILE NO.:	SL. 18C-AB. 75
REPORT DATE:	1-6-76
REPORT BY:	Gary N. Williams

EXXON RESEARCH & ENGINEERING CO.
ENGINEERING INFORMATION CENTER
FLORHAM PARK, N.J.

DATE RECEIVED:	3-4-75
DATE DISTILLED:	9-14-75
LAB ASSAY NO.:	2034
COST CENTER:	722110

ASSAY RUN BY:

EXXON COMPANY, U.S.A.
REFININGI DEPARTMENT
REFINERY LABORATORY
BAYTOWN, TEXAS

SPONSORED BY:

TABLE 1

CRUDE	
SYNTHOIL	SL. 18C-AB. 75

WHOLE CRUDE DATA *

GRAVITY		°API	5.9
SPECIFIC GRAVITY		60/60	1.0298
SULFUR		WT. %	0.22
MERCAPTAN SULFUR		WT. PPM	
POUR POINT		°F	25
NITROGEN		WT. %	0.79
WATER AND SEDIMENT		VOL. %	0.05
SALT CONTENT, NaCl		PTB	
REID VAPOR PRESSURE		PSI	
H_2S (DISSOLVED)		WT. PPM	0
NEUT. NO. (D664)		mg KOH/gm	0.36
VISCOSITIES:	KINEMATIC @	122°F, cSt	
		100°F, cSt	673
		80°F, cSt	1950
		60°F, cSt	
		40°F, cSt	
	SAYBOLT UNIVERSAL	122°F, SEC	
		100°F, SEC	3117
		80°F, SEC	9022
		60°F, SEC	
		40°F, SEC	

* After water & sediment had been removed. The sample as received had the following whole crude properties:

Gravity, °API	3.7
Water and Sediment	22.0
Viscosity	
Kinematic cSt @ 100°F	876.

TABLE 2

SYNTHOIL USBM | DATA INPUT AND CALCULATIONS | 5.9 DEG API | SL.18C-AB.75

TEMPERATURE DEG F	TEMPERATURE DEG C	NORM. VOL. PCT ON CRUDE	NORM. VOL. PCT CUM	NORM. VOL. PCT MID	GRAVITY DEG API	GRAVITY SPECIFIC	SUM OF SPEC GRAV X VOL PCT	RI AT 67 DEG C	DEG F AN. PT.	SUM OF VOL PCT X AN. PT.
		0.0	0.0	0.0						
		0.0	0.0	0.0						
		0.0	0.0	0.0						
68	20.0	0.0	0.0	0.0						
90	32.2	0.0	0.0	0.0						
115	46.1	0.0	0.0	0.0						
158	70.0	0.0	0.0	0.0						
185	85.0	0.0	0.0	0.0						
212	100.0	0.0	0.0	0.0						
248	120.0	0.0	0.0	0.0						
275	135.0	0.0	0.0	0.0						
302	150.0	0.16	0.16	0.08	35.4	0.8478	0.13565			
320	160.0	0.14	0.30	0.23	31.6	0.8676	0.25711	0.0	53	7.4
347	175.0	0.50	0.80	0.55	26.6	0.8950	0.70461	0.0	52	33.4
374	190.0	0.90	1.70	1.25	24.8	0.9053	1.51939	0.0	50	78.4
401	205.0	1.20	2.90	2.30	26.5	0.8956	2.59407	0.0	47	134.8
428	220.0	1.60	4.50	3.70	23.6	0.9123	4.05378	0.0	45	206.8
455	235.0	3.00	7.50	6.00	22.7	0.9176	6.80669	0.0	41	329.8
482	250.0	5.00	12.50	10.00	21.6	0.9242	11.42786	0.0	38	519.8
509	265.0	5.50	18.00	15.25	20.5	0.9309	16.54791	0.0	38	728.8
536	280.0	5.00	23.00	20.50	18.9	0.9408	21.25203	0.0	38	918.8
563	295.0	5.00	28.00	25.50	17.3	0.9509	26.00673	0.0	38	1108.8
590	310.0	5.20	33.20	30.60	16.0	0.9593	30.99519	0.0	38	1306.4
617	325.0	4.80	38.00	35.60	14.8	0.9672	35.63771	0.0	38	1488.8
650	343.3	5.60	43.60	40.80	13.0	0.9792	41.12144	0.0	39	1707.2
671	355.0	3.70	47.30	45.45	10.8	0.9944	44.80063	0.0	40	1855.2
698	370.0	4.70	52.00	49.65	8.4	1.0114	49.55437	0.0	40	2043.2
698+	370+	48.00	100.00		-4.3	1.1124	102.95058			

SYNTHOIL | SL. 18C-AB. 75

TABLE 3

TEMP., IVT, °F / TEMP., FVT, °F	GAS	68/ 158	275/ 302	302/ 401	401/ 509	509/ 650	650/ 698	302/ 509	302/ 698	347/ 698
YIELD RANGE, VOL. %			0.0-0.16	0.16-2.9	2.9-18.0	18.0-43.6	43.6-52.0	0.16-18.0	0.16-52.0	0.8-52.0
YIELD, VOL. %			0.16	2.74	15.1	25.6	8.4	17.84	51.84	51.2
GRAVITY, °API			35.4	26.2	21.6	15.9	9.4	22.3	16.9	16.8
SULFUR, WT. %			0.10	0.10	0.092	0.14	0.12	0.094	0.12	0.12
SULFUR, ppm										
MERCAP. SUL., ppm				80						
RVP, psi										
ANILINE PT., °F				49	39	38	40	41	39	39
FREEZING PT., °F				Too Dark						
CLOUD PT., °F				Too Dark						
POUR, °F					<-70	-30	20	<-70	-30	-25
SMOKE PT., mm				9	8			9		
COLOR, SAYBOLT										
Refractive Index@ 67°C				1.4694	1.4885	1.5145	1.5486	1.4860	1.5104	1.5110
Nitrogen, wt.%				0.30	0.29	0.32	0.47	0.29	0.34	0.34
AROMATICS, VOL. %				Too Dark						
KIN. VISC., cs, @ 100°F				1.51	2.62	7.29	35.9	2.42	5.58	5.68
150°F				0.98	1.55	3.39	10.2	1.42	2.76	2.78
210°F				0.67	0.97	1.85	3.91	0.92	1.55	1.57

TABLE 4

SYNTHOIL

SL. 18C-AB. 75

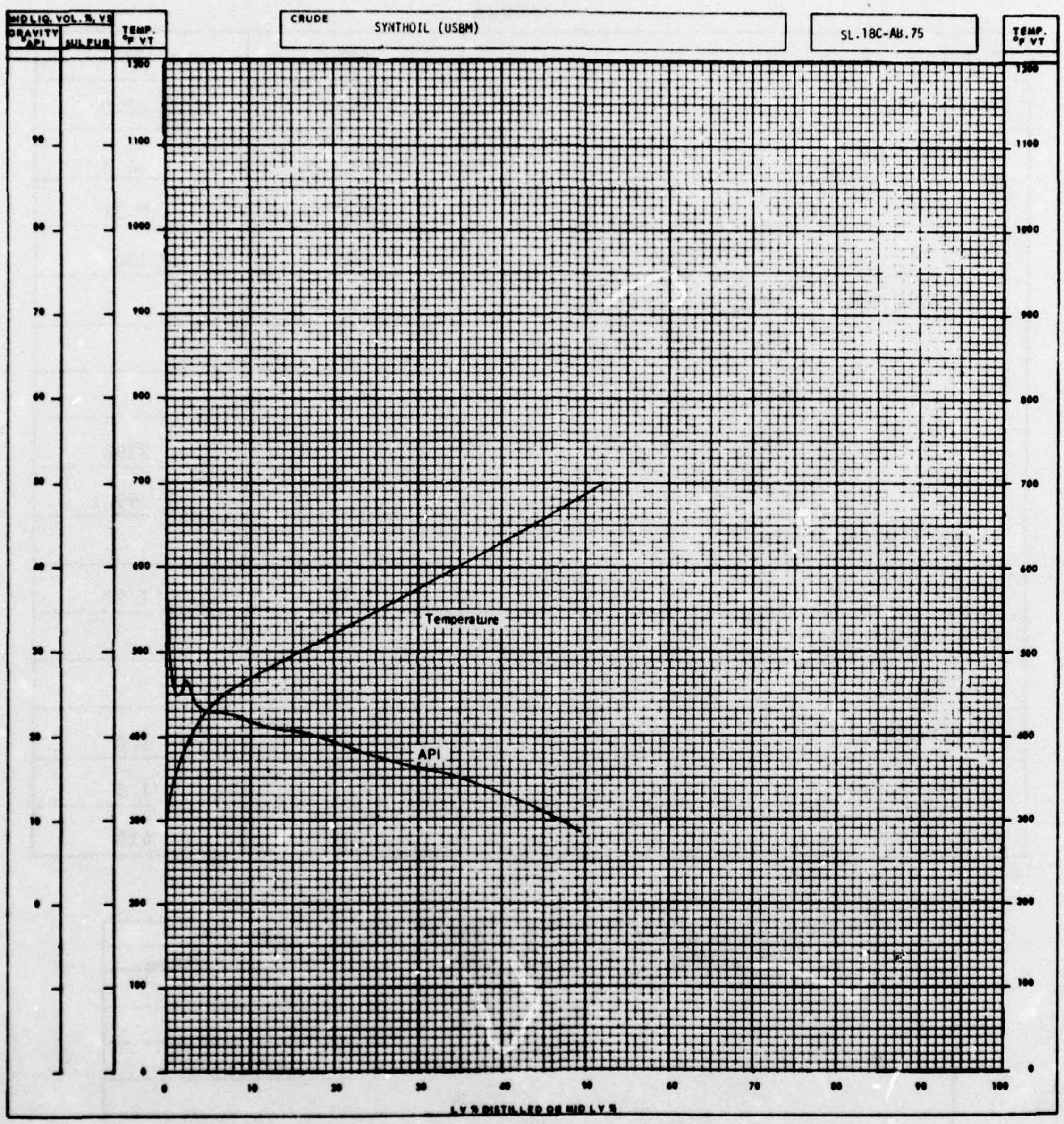
RESIDUA

CUT POINT, °F	650+	698+
YIELD, VOL. %	56.4	48.0
GRAVITY, °API	-2.4	-4.3
SULFUR, WT. %	0.28	0.31
POUR, °F	> 120	> 120
KINEMATIC VISC., @ 100°F		
122°F		
150°F		
175°F		2132
210°F		359.1
*SAYBOLT FUROL ~ 122°F		
NITROGEN, WT. %	1.12	1.22
CON CARBON, WT. %		
MNI, WT. %		
NICKEL, PPM		1.0
VANADIUM, PPM		7.5
IRON, PPM		419

* Converted from Kinematic

HI VAC C @ mm OF THE 698+ RESIDUA	VOL. % DIST.	TEMP., °F	
		1 mm	760 mm
	5		
	10		
	20		
	30		
	40		
	50		
	60		
	70		
	80		
	90		
	95		

GRAPH NO. 1



United States Department of the Interior
BUREAU OF MINES
4800 FORBES AVENUE
PITTSBURGH, PENNSYLVANIA 15213

Pittsburgh
Energy Research Center

August 28, 1974

Dr. Henry Shaw
Exxon Research and Engineering Co.
1600 E. Linden Avenue
Linden, New Jersey 07036

Dear Dr. Shaw:

Relative to your letter of June 27, 1974, a 250-lb sample of centrifuged product from our SYNTHOIL process has been shipped to you under separate cover. This product oil was made from Kentucky Coal, the source is a blend from Kentucky seams #9, 11, 12, and 13 which are mined together in Ohio County (Western Kentucky). Analysis of feed coal as received is listed below:

Proximate analysis, wt/pct

Moisture	4.2
Ash	16.5
Volatile matter	36.2
Fixed carbon	43.1

Ultimate analysis, wt/pct

Hydrogen	4.8
Carbon	60.7
Nitrogen	1.2
Oxygen	11.3
Sulfur	5.5
Ash	16.5

Forms of sulfur, wt/pct

Sulfate	0.47
Pyritic	3.08
Organic	1.95

Calorific value, Btu/lb 11,020
Rank: hvAb

Conditions were 4000 psig, 450° C, feeding a 35 percent solids slurry in lined-out, coal-derived recycle oil at 30 lbs per hour. This oil was produced using our nominally 1/2-ton/day unit with a 29 foot long catalytic reactor. Analytical assay data on this product oil is not yet available.

Of course, we will be very interested in any information you obtain on these samples. If there are any problems or questions, please contact me at (412) 892-2400, extension 677. Thank you for your interest in our work.

Sincerely,

Nestor J. Mazzocco

Nestor J. Mazzocco
Supervisory Chemical Engineer
Exploratory Engineering

NM:mjf

APPENDIX IX

H-COAL RUN (FEED COAL ANALYSIS) ASTM D-86 DISTILLATION

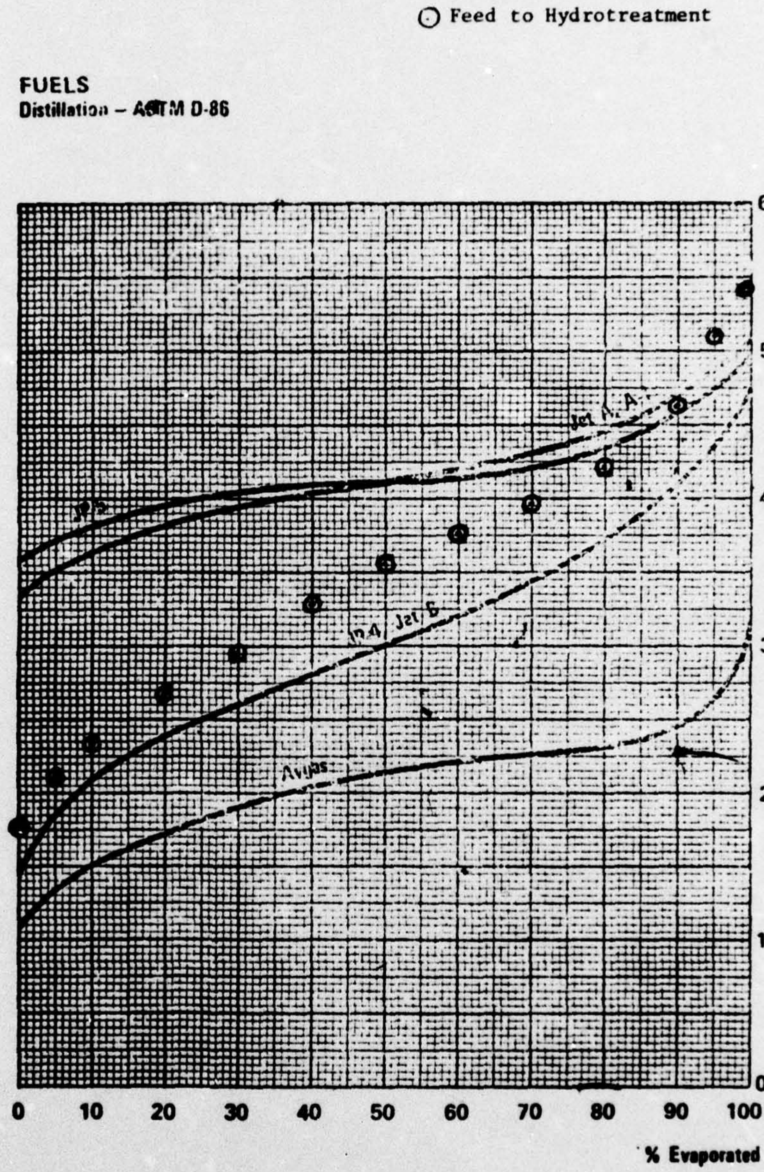
RUN 130-63 FEED COAL ANALYSIS

(Coal Feed Used to Prepare H-Coal Liquid Sample)

Coal Source	Monterey Coal Company
Moisture, W %	5.6
Proximate Analysis, Dry Basis, W %	
Ash	10.22
Volatile Matter	41.58
Fixed Carbon	48.20
Ultimate Analysis, Dry Basis, W %	
Carbon	70.09
Hydrogen	5.32
Nitrogen	1.22
Sulfur	4.27
Ash	10.22
Oxygen (Difference)	8.92
Sulfur in Ash, W %	1.18

Figure 1

H Coal "Atmospheric Overhead"



Ref: Turbine Fuel - BuMines, "Aviation Turbine Fuels," 1966
AvGas - BuMines, "Aviation Fuels," 1964

APPENDIX X

JFTOT RESULTS

FIGURE D-1

ALCOR JET FUEL THERMAL OXIDATION TEST

DATE 8-25 400 PSI TEST NO. D-1

FUEL DESCRIPTION Jet A
RIG NO. ERE-1 OPERATOR W. DAVIS
AMBIENT TEMP., °F 77

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME
FUEL AERATED 12:30
HEATER ON 12:40

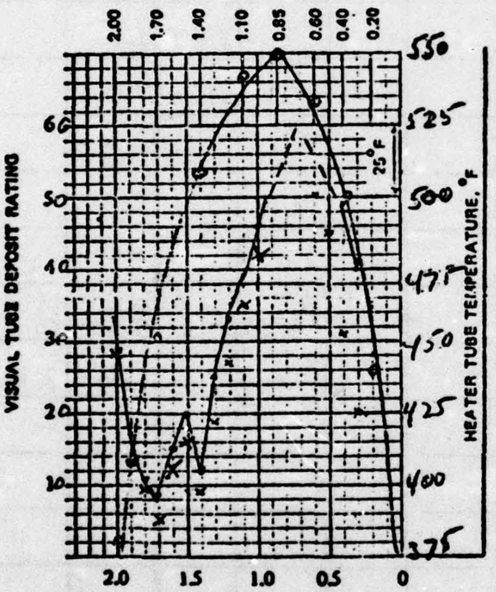
HEATER TUBE TEMPERATURE CONTROL (MAX.) 550°F

PROFILE TEMPERATURES

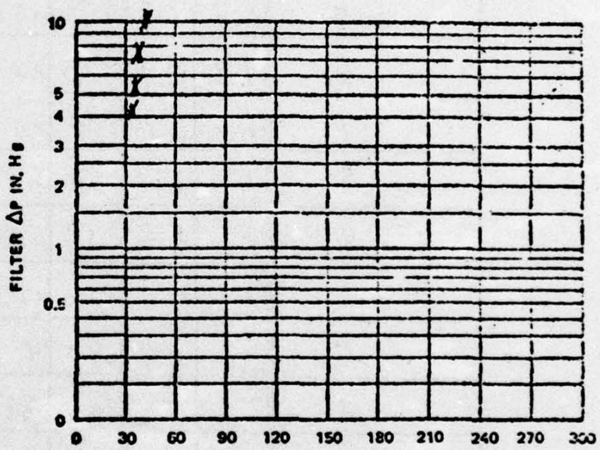
THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	553
0.20	443
0.40	503
0.60	537
1.10	545
1.40	512
1.70	455
2.00	382
0.85	553

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30 34	4.1
60 36	5.6
90 38	6.5
120 39	7.9
150 40	8.5
180 42	9.7
210 42.4	10.0
240	
270	
300	

FILTER BYPASSED AT 42.4 MIN.



DISTANCE FROM FUEL OUTLET INCHES



TEST TIME IN MINUTES 150
40 DROPS/SEC. 18

TEST FUEL CONSUMED 450 ml

DEPOSIT CODE:

0 - NO VISIBLE DEPOSITS
1 - HAZE OR DULLING, NO COLOR
2 - BARELY VISIBLE DISCOLORATION
3 - LIGHT TAN
4 - HEAVIER THAN CODE 3

REMARKS Ruf. ltr. E. C. A1

TABLE D-1

JET A

TUBE RATING REPEATIBILITY AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE - 8-25-75

DATE TUBES RECEIVED 12-72 ① RUN # D-1

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW		USED		Tube Number		VISUAL			
	SPUN	SPOT	SPUN	SPOT			CODE	POSITION		
0.3	1.8	3.6	20.2	41.0			1	1.8-1.6	6	
.4	1.6	2.9	31.2	49.2			2	1.6-	1.5	
.5	0.8	2.3	45.2	>50			3	1.5-	135	
.6	1.7	3.7	50.2	>50			4	0.5-	0.3	
.7	0.0	1.7	>50	>50			4+	1.1-	0.5	
.8	1.0	2.9	>50	>50			1		0	
.9	1.2	2.8	>50	>50			Peacocking		0.3-	0.1
1.0	2.7	4.1	42.0	45.8			Peacockin		1.35-	1.1
.1	3.0	4.9	34.5	41.1						
.2	3.0	5.2	26.9	33.1						
.3	3.9	6.4	18.9	24.9						
.4	3.7	6.7	9.1	12.0						
.5	3.6	5.9	16.1	20.0						
.6	3.1	5.1	12.0	15.0						
.7	2.7	5.7	5.3	6.5						
.8	9.0	11.5	9.8	11.0						
.9	14.5	18.6	13.1	17.2						
2.0	30.2	32.9	28.2	33.0						
MAX. 2.1	46.2	48.2	45.0	46.8						

FIGURE D-2

ALCOR JET FUEL THERMAL OXIDATION TEST

DATE 8·27·75 400 PSI TEST NO. D-2

FUEL DESCRIPTION PARAHO DIST. CUT #4

RIG NO. ERE-1 OPERATOR W. DAVIS

AMBIENT TEMP., °F 72

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	3	°F

CLOCK TIME

FUEL AERATED 0845

HEATER ON 1010

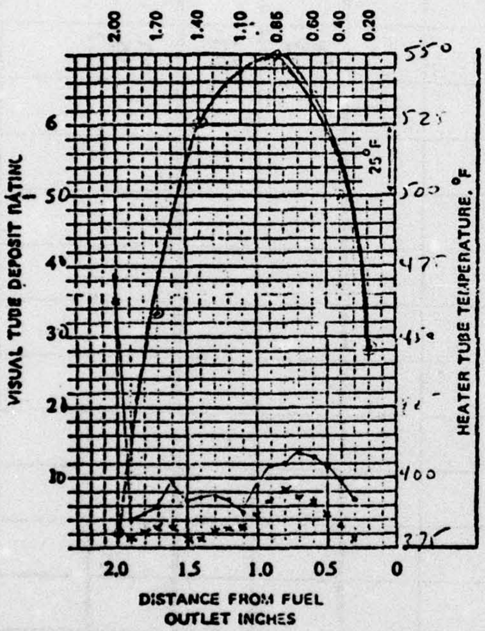
HEATER TUBE TEMPERATURE CONTROL (MAX.) 550 °F

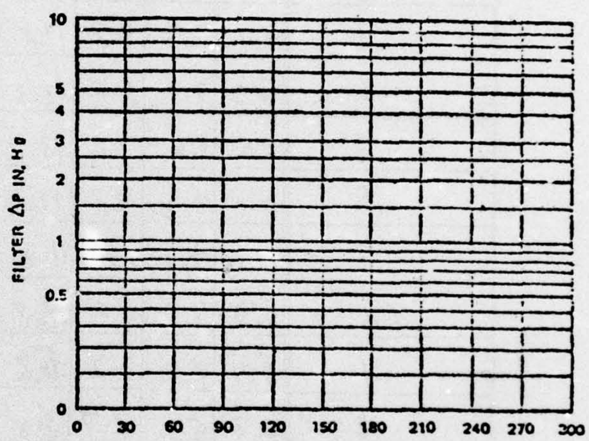
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	553
0.20	449
0.40	503
0.60	538
1.10	546
1.40	513
1.70	461
2.00	383
0.85	553

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.0
60	0.0
90	0.0
120	0.0
150	
180	
210	
240	
270	
300	

FILTER BYPASSED AT ______ MIN.





TEST TIME IN MINUTES 150

40 DROPS/SEC. 18

TEST FUEL CONSUMED 455 ml

DEPOSIT CODE:

0 – NO VISIBLE DEPOSITS

1 – HAZE OR DULLING, NO COLOR

<2 – BARELY VISIBLE DISCOLORATION

3 – LIGHT TAN

4 – HEAVIER THAN CODE 3

A-0.

REMARKS Prefilter Color = Very light

TABLE D-2

PARAHO JET A (11B)

TUBE RATING REPEATIBILITY AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE - 8-27-75

DATE TUBES RECEIVED 12/72 RUN # D-2

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW		USED	Tube Number			VISUAL			
	SPUN	SPOT	SPUN	SPOT			COLOR	POSITION		
0.3	-0	1.6	1.2	6.8						
.4	-0	2.9	3.7	9.8			<2	8 -	.55	
.5	-0	3.2	4.7	11.8						
.6	0.0	3.7	6.5	12.8						
.7	0.0	3.6	7.6	13.7						
.8	0.0	3.2	8.3	12.0						
.9	0.0	3.7	6.7	11.8						
1.0	0.9	3.8	4.8	8.8						
.1	0.9	4.2	3.2	5.2						
.2	0.3	5.3	2.7	6.8						
.3	0.2	3.3	2.1	7.5						
.4	-0	5.5	1.4	7.1						
.5	-0	5.0	1.5	6.7						
.6	1.8	6.4	2.8	9.9						
.7	1.9	3.7	3.0	6.0						
.8	1.0	2.5	2.1	4.8						
.9	0.8	2.0	1.6	4.0						
2.0	31.1	38.0	34.7	38.7						
MAX. 2.1	45.2	47.1	44.2	46.8						

FIGURE D-3

ALCOR JET FUEL THERMAL OXIDATION TEST

DATE 8-27-75 400 PSI TEST NO. D-3

FUEL DESCRIPTION Paraffinic Dist Cut #4
RIG NO. ERC-1 OPERATOR W. Davis
AMBIENT TEMP., °F 77°

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	3	°F

CLOCK TIME

FUEL AERATED 1330
HEATER ON 1345

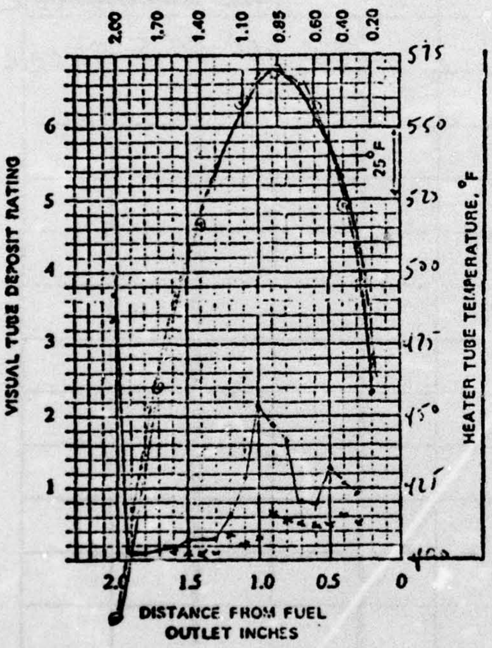
HEATER TUBE TEMPERATURE CONTROL (MAX.) 570 °F

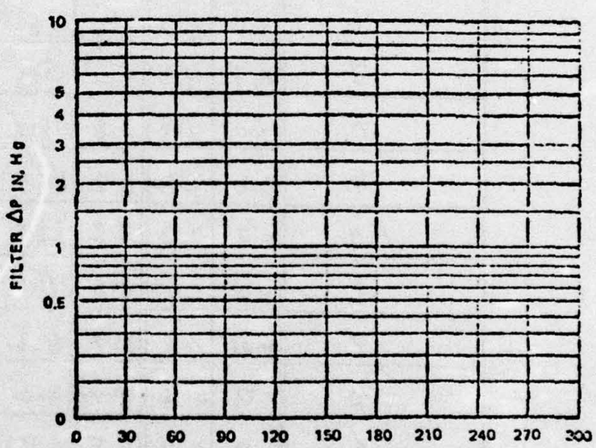
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	573
0.20	461
0.40	525
0.60	560
1.10	562
1.40	520
1.70	463
2.00	385
0.85	573

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.0
60	0.0
90	0.0
120	0.0
150	0.0
180	
210	
240	
270	
300	

FILTER BYPASSED AT ________ MIN.





TEST TIME IN MINUTES 150

40 Drops/Sec. 17.8

TEST FUEL CONSUMED 455 ml

DEPOSIT CODE:

0 – NO VISIBLE DEPOSITS
1 – HAZE OR DULLING, NO COLOR
2 – BARELY VISIBLE DISCOLORATION
3 – LIGHT TAN (+3 streak)
4 – HEAVIER THAN CODE 3

G-0

REMARKS Prefilter Filter ~~[illegible]~~

TABLE D-3

PARAHO 11B JET A

TUBE RATING REPEATIBILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE - 8-27-71

DATE TUBES RECEIVED 12/72 RUN # D-3

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW		USED		Tube Number		VISUAL			
	SPUN	SPOT	SPUN	SPOT			COLOR	POSITION		
0.3	3.7	9.2	5.3	8.6						
.4	4.0	8.1	6.2	10.4				~~[illegible] streak~~		
.5	1.7	5.8	4.9	12.7			3+	1.1 -	0.5	Streak
.6	1.0	5.3	4.4	7.8						
.7	0.7	4.8	5.2	8.2						
.8	1.0	4.9	5.8	16.8						
.9	0.0	2.2	6.2	18.9						
1.0	-0	1.8	3.3	21.5						
.1	-0	1.6	2.2	11.0						
.2	[illegible]	2.8	1.9	6.2						
.3	-0	0.4	0.8	3.2						
.4	-0	0.4	0.5	3.0						
.5	0.0	1.2	0.7	2.6						
.6	0.2	1.0	0.8	1.8						
.7	-0	0.6	-0	1.3						
.8	-0	-0	-0	0.8						
.9	-0	-0	-0	0.8						
2.0	28.2	26	33.8	36.7						
MAX. 2.1	45.5	46.8	45.3	46.7						

FIGURE 4-1
8-27-75

PARAHO DIST. CUT 4 RUN 11-B
JFTOT D-2, D-3

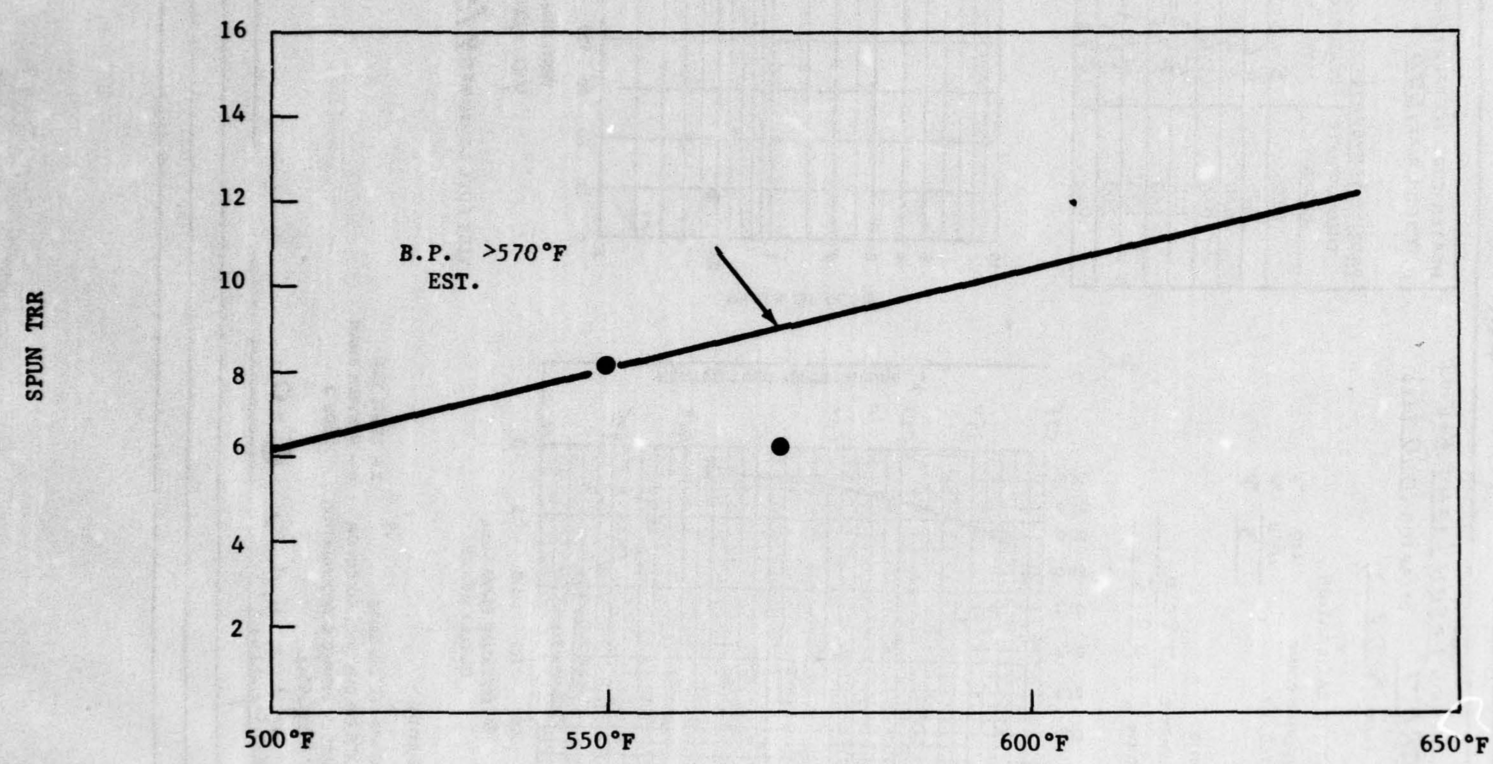


FIGURE D-4

ALCOR JET FUEL THERMAL OXIDATION TEST

DATE 8-28-75 400 PSI TEST NO. D-4

FUEL DESCRIPTION Tosco Light Blend
RIG NO. ERE-1 OPERATOR W. Davis
AMBIENT TEMP., °F 77

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	3	°F

CLOCK TIME

FUEL AERATED 0900
HEATER ON 0915

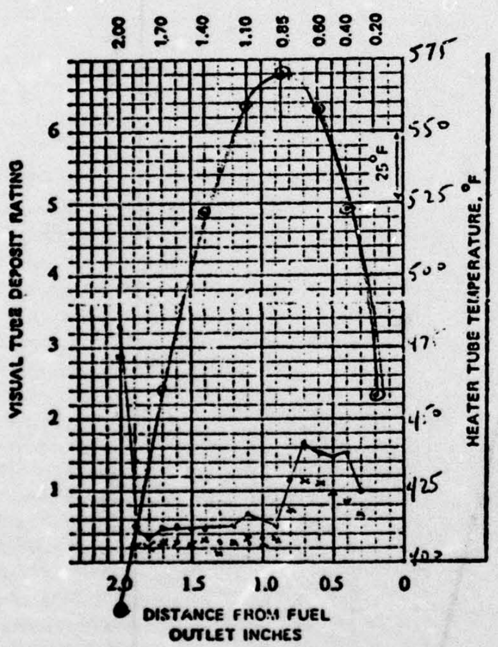
HEATER TUBE TEMPERATURE CONTROL (MAX.) 570 °F

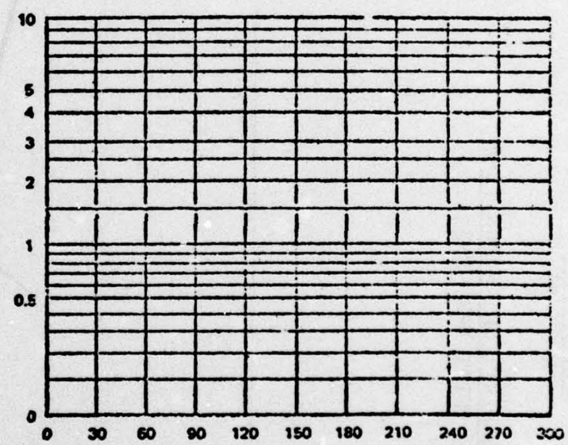
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	573
0.20	461
0.40	525
0.60	561
1.10	562
1.40	525
1.70	463
2.00	385
0.85	573

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.0
60	0.0
90	0.0
120	0.0
150	0.0
180	
210	
240	
270	
300	

FILTER BYPASSED AT ____ MIN.





TEST TIME IN MINUTES 150
4.0 DROPS/SEC. 17.4

TEST FUEL CONSUMED 470 ml

DEPOSIT CODE:

- 0 – NO VISIBLE DEPOSITS
- 1 – HAZE OR DULLING, NO COLOR
- 2 – BARELY VISIBLE DISCOLORATION
- 3 – LIGHT TAN
- 4 – HEAVIER THAN CODE 3

streaked

REMARKS Prefilter, Filter G-0

TABLE D-4

TOSCO 17B JP-4 BLEND

TUBE RATING REPEATIBILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE - 8-28-75

DATE TUBES RECEIVED 12/72 RUN # D-4

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW		USED	Tube Number			VISUAL			
	SPUN	SPOT	SPUN	SPOT			COLOR	POSITION		
0.3	-0	1.0	6.5	10.0			2	2-	0	Several Streaks
.4	0.7	1.7	8.5	16.2						
.5	1.1	2.5	9.7	14.6						
.6	0.9	1.0	11.2	15.2			2	.8	.3	
.7	0.2	1.0	11.7	16.8						
.8	0.5	0.9	7.6	11.7						
.9	0.0	0.1	3.3	5.2						
1.0	-0	2.0	2.3	3.5						
.1	1.2	6.9	3.8	6.8						
.2	0.0	2.0	2.4	4.8						
.3	-0	2.1	1.7	2.8						
.4	0.9	3.0	3.3	4.3						
.5	0.8	2.0	2.2	4.5						
.6	0.5	1.0	2.5	5.0						
.7	0.2	0.8	2.7	4.8						
.8	0.0	0.2	2.1	3.2						
.9	1.1	2.0	2.2	5.0						
2.0	24.0	27.0	28.4	32.7						
MAX. 2.1	44.8	46.7	45.2	46.3						

FIGURE 4-2
8-28-75

TOSCO 17-B LIGHT BLEND
JFTOT D-4

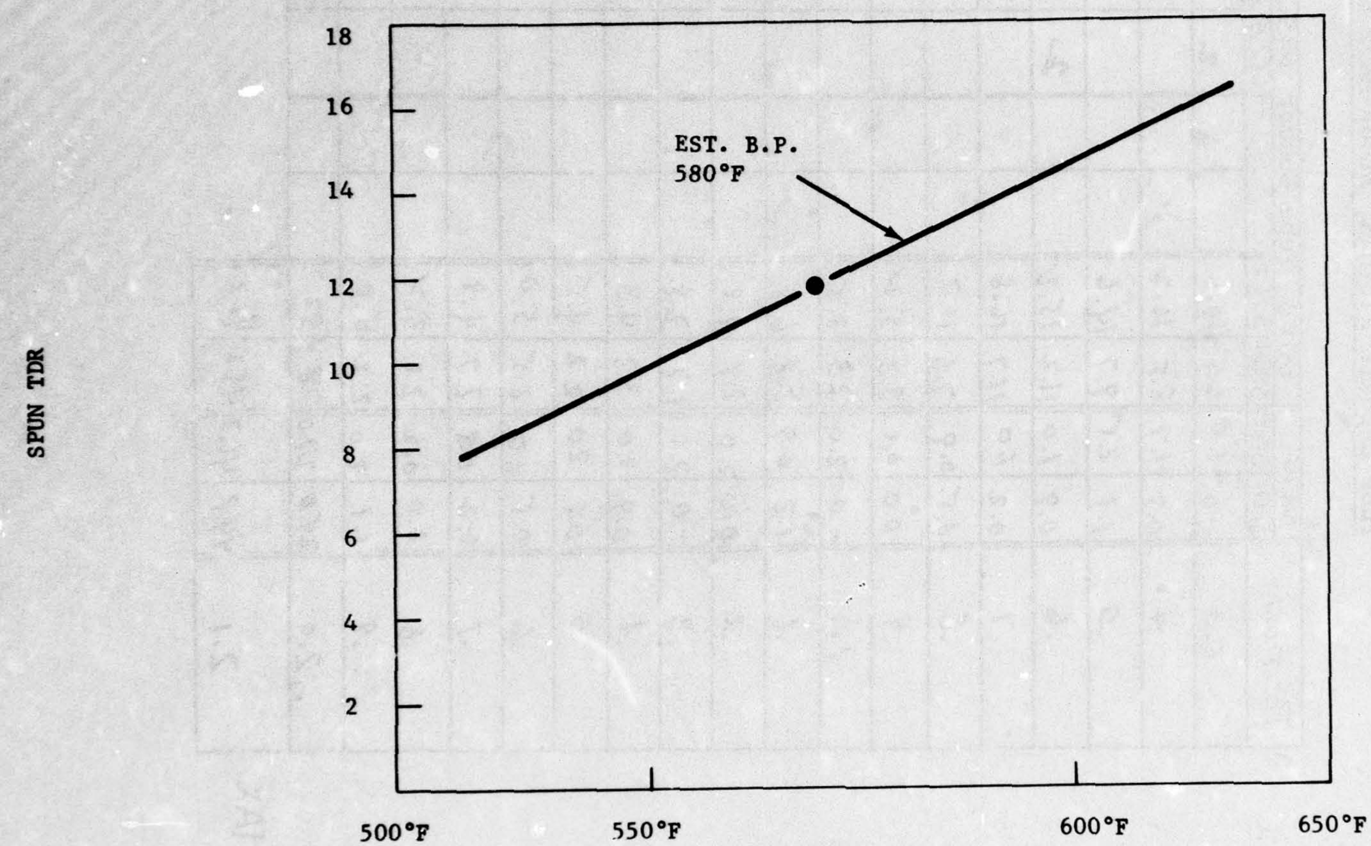


FIGURE D-5

ALCOR JET FUEL THERMAL OXIDATION TEST

DATE 8-28-75   400 PSI   TEST NO. D-5

FUEL DESCRIPTION TOSCO HEAVY BLEND

RIG NO. ERE-1   OPERATOR W. DAVIS

AMBIENT TEMP., °F 77

TEMPERATURE CALIBRATION

TRUE MELTING POINT 449 °F

INDICATED MP 452 °F

ERROR 3 °F

CLOCK TIME

FUEL AERATED 1305

HEATER ON 1315

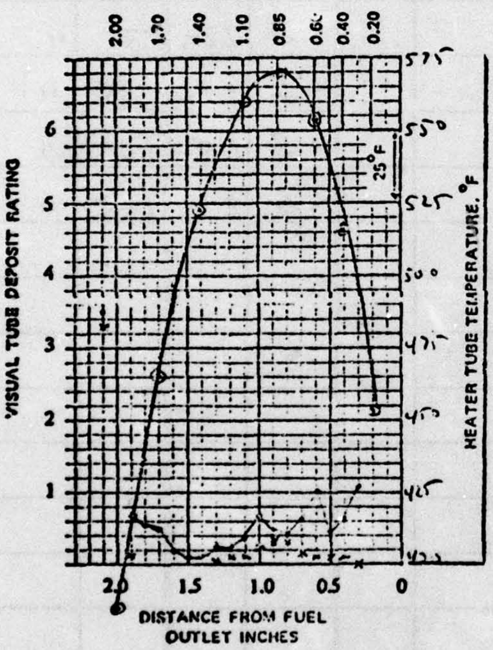
HEATER TUBE TEMPERATURE CONTROL (MAX.) 570 °F

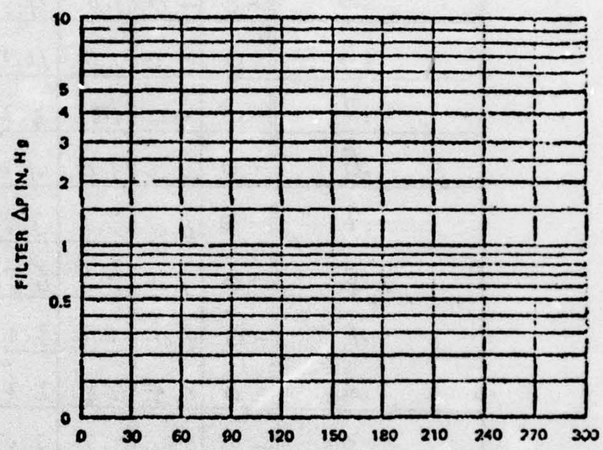
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	573
0.20	457
0.40	519
0.60	557
1.10	563
1.40	526
1.70	468
2.00	389
0.85	573

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.05
60	0.0
90	0.0
120	0.0
150	0.0
180	
210	
240	
270	
300	

FILTER BYPASSED AT —— MIN.





40 DROPS/SEC, 17.8

TEST FUEL CONSUMED 460 ml

DEPOSIT CODE:

0 – NO VISIBLE DEPOSITS
1 – HAZE OR DULLING, NO COLOR
2 – BARELY VISIBLE DISCOLORATION
3 – LIGHT TAN
4 – HEAVIER THAN CODE 3

SEVERAL STREAKS

REMARKS Prefilter Color = B-1

TABLE D-5
TOSCO 17B JET A BLEND

TUBE RATING REPEATIBILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE - 8-28-75

DATE TUBES RECEIVED 12/72 RUN # D-5

Tube Deposit Ratings, ALCOR Mark 8

	POSITION	NEW SPUN	NEW SPOT	USED SPUN	USED SPOT	Tube Number		VISUAL CODE	POSITION		
	0.3	-0	0.8	0.0	10.8			<3	.5-.3	Streck	
	.4	-0	1.0	0.6	6.5			<3	.62-.	63	"
	.5	-0	-0	1.0	4.5			<3	1.1-	.85	"
	.6	-0	0.0	1.0	10.1			<3	1.5-	1.08	"
	.7	-0	-0	1.9	6.2			<3	2-	1.55	"
	.8	-0	0.0	3.0	4.2						
	.9	-0	0.0	3.1	3.9						
	1.0	-0	1.0	2.3	6.8						
	.1	-0	1.0	1.2	3.8						
	.2	-0	0.5	0.8	2.2						
	.3	-0	0.8	0.2	2.5						
	.4	-0	0.0	-0	1.0						
	.5	-0	1.0	-0	0.8						
	.6	-0	2.0	-0	2.0						
	.7	-0	1.0	-0	4.9						
	.8	-0	1.8	0.0	5.8						
	.9	-0	3.8	1.1	6.2						
	2.0	31.2	37.2	32.5	34.5						
MAX.	2.1	45.1	46.7	45.3	46.8						

FIGURE D-6

ALCOR JET FUEL THERMAL OXIDATION TEST

DATE 8-29-75 TEST NO. D-6

400 PSI

FUEL DESCRIPTION Tosco Heavy Blend
RIG NO. ERE-1 OPERATOR W. Davis
AMBIENT TEMP., °F 77

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	3	°F

CLOCK TIME

FUEL AERATED 0940
HEATER ON 0950

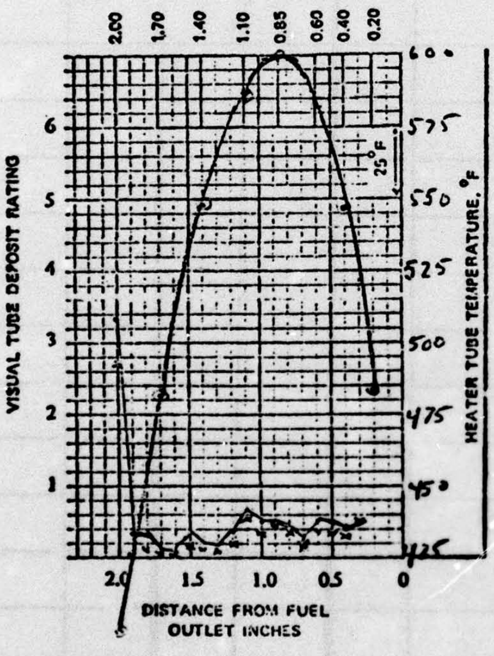
HEATER TUBE TEMPERATURE CONTROL (MAX.) 600 °F

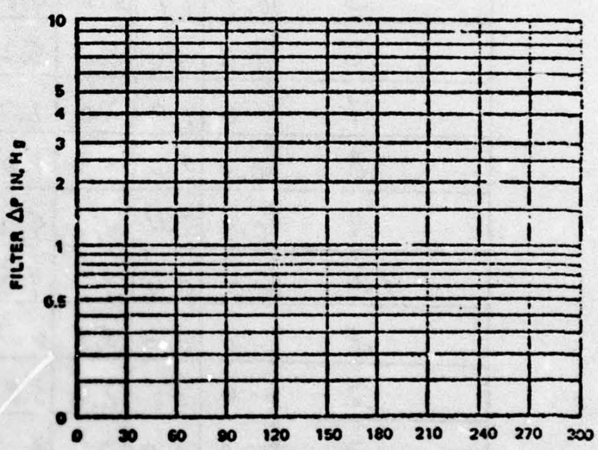
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	603
0.20	486
0.40	550
0.60	586
1.10	590
1.40	551
1.70	485
2.00	403
0.8	603

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.0
60	0.0
90	0.0
120	0.0
150	0.0
180	
210	
240	
270	
300	

FILTER BYPASSED AT ____ MIN.





150

40 Drops/sec. 18

TEST FUEL CONSUMED 465 ml

DEPOSIT CODE:

0 – NO VISIBLE DEPOSITS
1 – HAZE OR DULLING, NO COLOR
2 – BARELY VISIBLE DISCOLORATION
3 – LIGHT TAN
4 – HEAVIER THAN CODE 3

REMARKS Prefilter Filter = B-1

TABLE D-6
TOSCO 17B JET A BLEND

TUBE RATING REPEATIBILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE - 8-29-75

DATE TUBES RECEIVED 12/72 RUN # D-6

Tube Deposit Ratings, ALCOR Mark 8

	POSITION	NEW		USED		Tube Number		VISUAL			
		SPUN	SPOT	SPUN	SPOT			CODE POSITION			
	0.3	2.8	5.8	5.0	4.7			2	2 —	.3	
	.4	0.8	1.8	3.2	4.0						
	.5	0.7	1.7	3.8	4.8						
	.6	0.3	1.2	3.9	5.2						
	.7	-0	1.0	2.0	2.2						
	.8	0.1	1.2	3.9	4.2						
	.9	0.8	2.4	4.6	5.1						
	1.0	-0	0.6	3.9	4.8						
	.1	-0	0.0	5.8	6.7						
	.2	-0	0.8	2.1	3.8						
	.3	-0	0.0	0.8	2.0						
	.4	-0	1.1	1.0	2.4						
	.5	0.9	2.3	1.9	3.6						
	.6	-0	0.4	0.7	1.0						
	.7	-0	0.9	0.4	1.5						
	.8	0.0	0.6	1.1	3.6						
	.9	0.9	2.3	0.2	3.7						
	2.0	27.9	30.8	27.0	33.7						
MAX.	2.1	45.2	41.7	45.2	41.2						

FIGURE 4-3
8-29-75

TOSCO 17-B HEAVY BLEND
JFTOT D-5, D-6

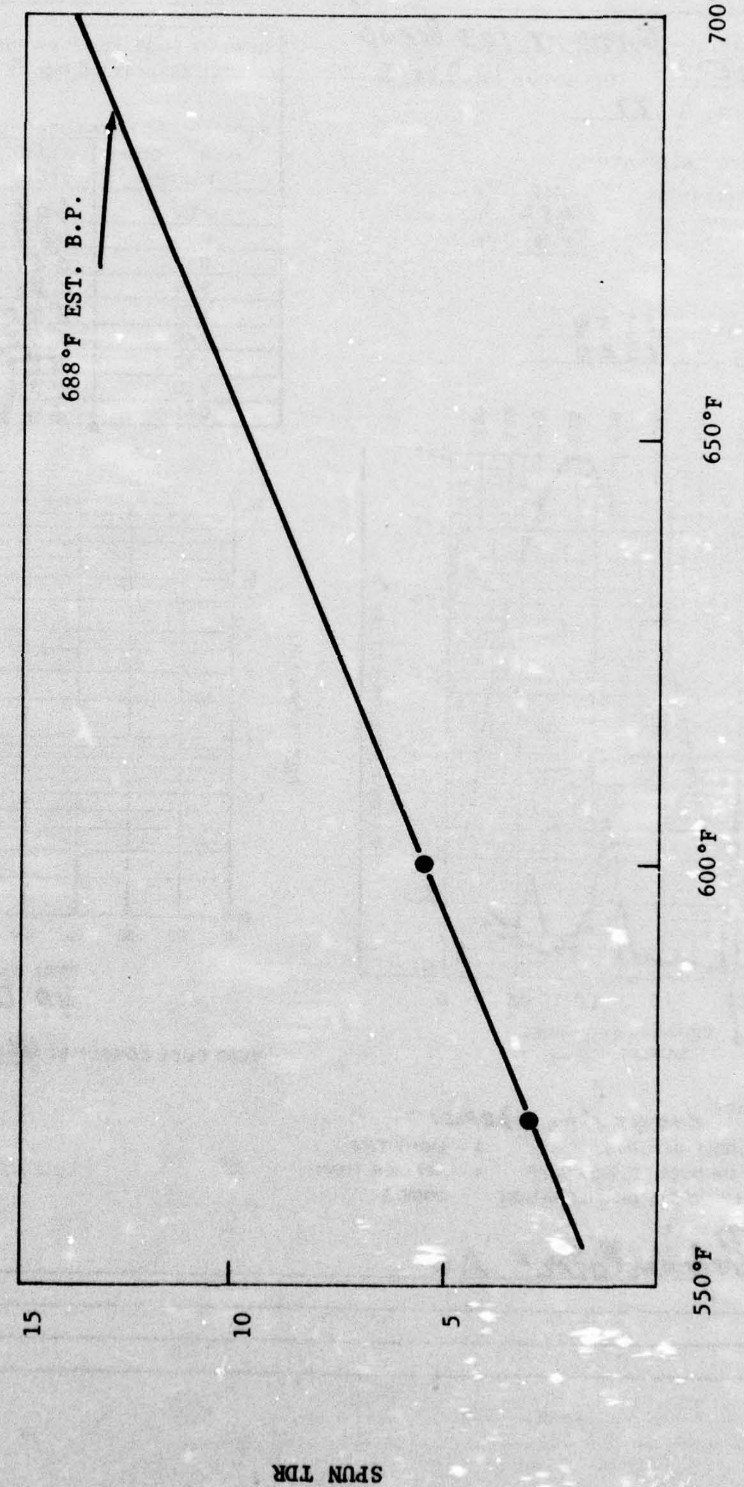


FIGURE D-7

ALCOR JET FUEL THERMAL OXIDATION TEST

DATE 10-29-75 — 400 PSI — TEST NO. D-7

FUEL DESCRIPTION GARRETT 103 BLEND
RIG NO. ERE-1 OPERATOR W. DAVIS
AMBIENT TEMP., °F 77

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 1258
HEATER ON 1320

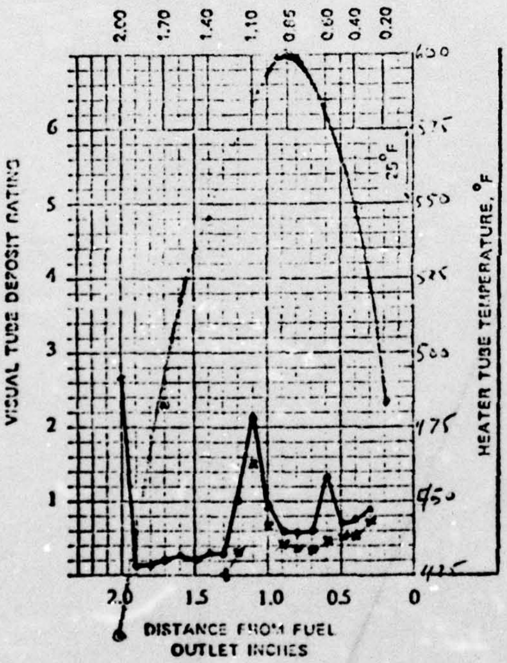
HEATER TUBE TEMPERATURE CONTROL (MAX.) 600 °F

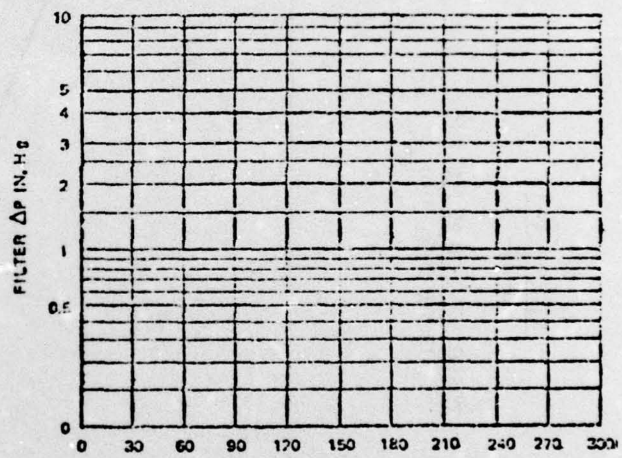
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	603
0.20	487
0.40	551
0.60	586
1.10	590
1.40	548
1.70	485
2.00	406
0.85	603

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.0
60	0.0
90	0.0
120	0.0
150	0.0
180	
210	
240	
270	
300	

FILTER BYPASSED AT ——— MIN.





TEST TIME IN MINUTES 150
40 DROPS/SEC 18.4

TEST FUEL CONSUMED 460 ml

DEPOSIT CODE: LIGHT GRAY DEPOSIT

0 – NO VISIBLE DEPOSITS
1 – HAZE OR DULLING, NO COLOR
2 – BARELY VISIBLE DISCOLORATION
3 – LIGHT TAN
4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = A0

TABLE D-7

GARRETT 103 BLEND JET A

TUBE RATING REPEATIBILITY AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE - 10-29-75

DATE TUBES RECEIVED 12-72 RUN # D-7

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW SPUN	NEW SPOT	USED SPUN	USED SPOT	Tube Number		VISUAL COKE POSITION			
0.3	6.1	8.0	7.3	9.0						
.4	2.7	4.0	5.4	7.8			1-	1.2-	1.0	LIGHT GRAY DEPOSIT
.5	1.8	4.0	5.0	7.0			2	1.25-	1.05	
.6	1.3	3.5	4.3	13.3						
.7	0.3	2.2	3.1	6.0						
.8	0.0	2.2	3.8	5.9						
.9	-0	1.1	4.0	6.0						
1.0	-0	2.1	6.6	9.0						
.1	-0	1.0	15.6	21.5						
.2	-0	0.9	3.7	10.1						
.3	-0	0.0	-0	3.0						
.4	-0	-0	-0	3.0						
.5	-0	-0	-0	2.0						
.6	-0	-0	-0	2.3						
.7	-0	0.0	-0	2.0						
.8	-0	-0	-0	1.2						
.9	-0	1.3	-0	1.3						
2.0	3.2	3.8	23.2	26.5						
MAX.			45.5	46.3						

FIGURE 4-4
10-29-75

GARRETT 103 BLEND
JFTOT D-7

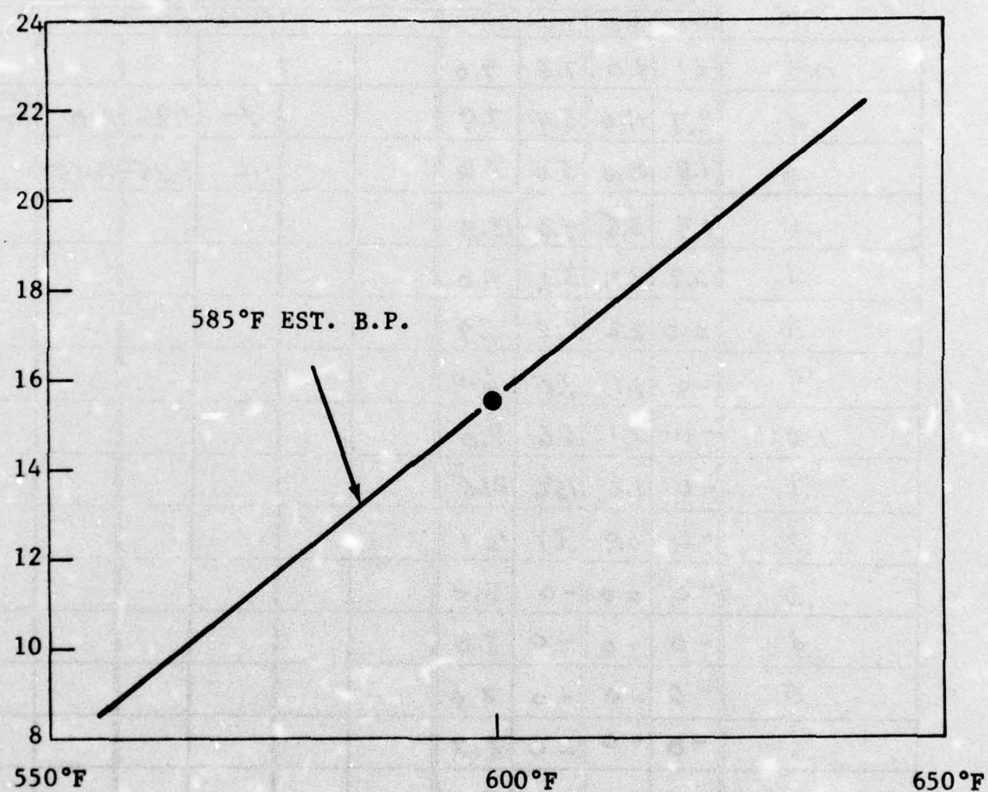


FIGURE D-8

ALCOR JET FUEL THERMAL OXIDATION TEST

DATE 10-30-75 TEST NO. D-8

400 PSI

FUEL DESCRIPTION SYNTHOIL 10% BLEND
RIG NO. ERE-1 OPERATOR W. DAVIS
AMBIENT TEMP., °F 77°

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	552	°F
ERROR	3	°F

CLOCK TIME

FUEL AERATED 0900
HEATER ON 0912

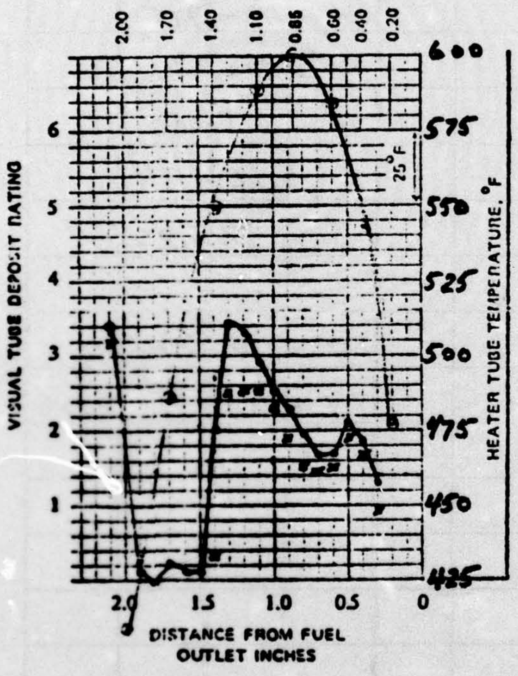
HEATER TUBE TEMPERATURE CONTROL (MAX.) 600 °F

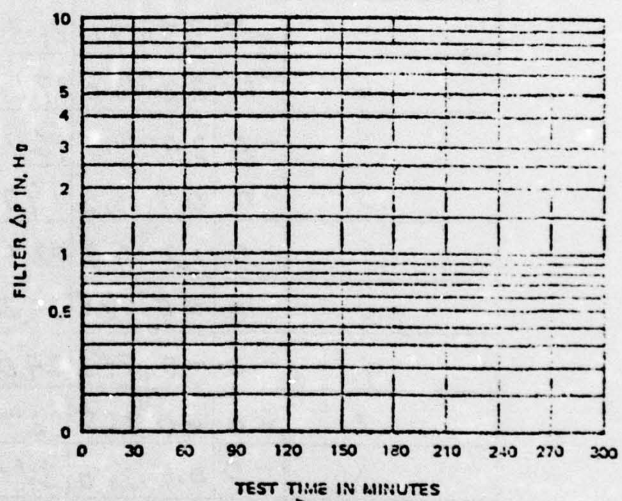
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	603
0.20	480
0.40	546
0.60	587
1.10	592
1.40	552
1.70	489
2.00	408
0.85	603

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.0
60	0.0
90	0.0
120	0.0
150	0.0
180	
210	
240	
270	
300	

FILTER BYPASSED AT ——— MIN.





40 DROPS/SEC. 18.2

TEST FUEL CONSUMED 465 ml

DEPOSIT CODE: 4+ streak

0 – NO VISIBLE DEPOSITS
1 – HAZE OR DULLING, NO COLOR
2 – BARELY VISIBLE DISCOLORATION
3 – LIGHT TAN
4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = A 0

TABLE D-8

SYNTHOIL 105 BLEND JET A

TUBE RATING REPEATABILITY AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE - 10-30-75

DATE TUBES RECEIVED 12/72 RUN # D-8

Tube Déposit Ratings, ALCOR Mark 8

POSITION	NEW SPUN	NEW SPOT	USED SPUN	USED SPOT	Tube Number		VISUAL CODE	POSITION		
0.3	2.0	3.0	9.0	12.8			4	1.3 –	975	
.4	1.1	2.1	16.3	18.4			2 +	.975 –	.675	
.5	0.7	3.7	19.1	21.3			4 +	.675 –	.60	
.6	−0	2.0	15.0	17.1			4	.60 –	.50	
.7	−0	2.9	14.5	16.7			3	.50 –	.375	
.8	−0	0.7	15.6	19.7						
.9	−0	1.2	19.3	22.4			1.4 –	1.0	Streak	
1.0	−0	0.8	22.5	25.2			1.5 –	1.0	#4 Streak	
.1	−0	−0	25.2	29.0						
.2	−0	−0	25.5	32.7						
.3	−0	0.5	25.0	34.1						
.4	0.0	1.5	3.0	20.0						
.5	−0	2.2	0.0	1.0						
.6	−0	3.0	−0	1.0						
.7	−0	2.8	−0	2.1						
.8	−0	2.1	−0	−0						
.9	−0	4.5	0.0	0.9						
2.0	8.9	13.5	32.0	34.0						
MAX. 2.1	45.2	47.1	45.2	46.5						

FIGURE D-9

ALCOR JET FUEL THERMAL OXIDATION TEST

DATE 10-30-75 400 PSI TEST NO. D-9

FUEL DESCRIPTION SYNTHOIL 105 BLEND

RIG NO. ERE-1 OPERATOR W. DAVIS

AMBIENT TEMP., °F 77

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 1225

HEATER ON 1238

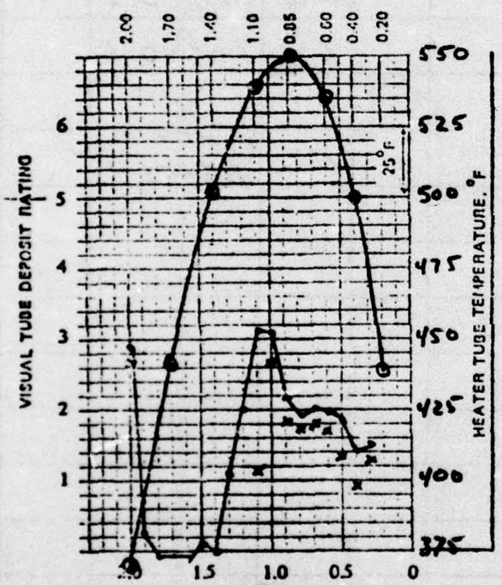
HEATER TUBE TEMPERATURE CONTROL (MAX.) 550 °F

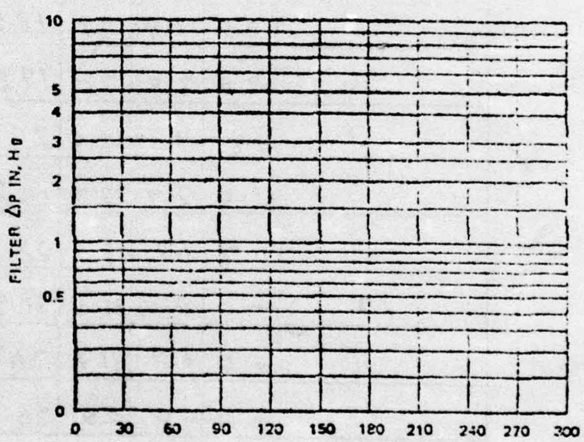
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	553
0.20	442
0.40	502
0.60	538
1.10	541
1.40	504
1.70	495
2.00	372
0.85	553

TEST TIME MINUTES	FILTER INCHES Hg
0	0.0
30	0.0
60	0.0
90	0.0
120	0.0
150	0.0
180	
210	
240	
270	
300	

FILTER BYPASSED AT ——— MIN.





40 DROPS/SEC, 18.0

TEST FUEL CONSUMED 460 ml

DEPOSIT CODE: 4-Streak

0 – NO VISIBLE DEPOSITS
1 – HAZE OR DULLING, NO COLOR
2 – BARELY VISIBLE DISCOLORATION
3 – LIGHT TAN
4 – HEAVIER THAN CODE 3

REMARKS: Prefilter Color = A.0

TABLE D-9

SYNTHOIL 105 BLEND JET A

TUBE RATING REPEATABILITY AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE - 10-30-75

DATE TUBES RECEIVED 12-72 RUN # D-9

Tube Deposit Ratings, ALCOR Mark 8 @ 550°F

POSITION	NEW SPUN	NEW SPOT	USED SPUN	USED SPOT	Tube Number		VISUAL CODE	VISUAL POSITION		
0.3	12.0	15.0	12.8	15.2			<2	1.10	0.5	
.4	6.0	8.0	9.2	14.1			<4	1.05	0.6	
.5	5.5	7.4	13.2	18.6						
.6	3.0	3.8	17.0	19.8			4	5/4 = 2K 1.3	0.45	
.7	1.8	4.3	18.0	20.0						
.8	1.0	2.7	17.3	19.2						
.9	0.7	1.8	18.1	22.0						
1.0	-0	0.0	26.8	30.9						
.1	-0	0.7	11.2	31.7						
.2	-0	-0	0.0	20.0						
.3	-0	-0	-0	11.0						
.4	-0	1.0	-0	-0						
.5	0.6	1.2	-0	1.0						
.6	-0	-0	-0	-0						
.7	-0	1.0	-0	-0						
.8	-0	-0	-0	-0						
.9	-0	0.9	-0	2.2						
2.0	1.0	3.5	26.5	29.0						
MAX. 2.1	45.5	47.0	45.0	46.0						

FIGURE D-10

ALCOR JET FUEL THERMAL OXIDATION TEST

DATE 10-31-75   400 PSI   TEST NO. D-10

FUEL DESCRIPTION SYNTHOIL 105 BLEND

RIG NO. ERE-1   OPERATOR W. DAVIS

AMBIENT TEMP., °F 77

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 0909

HEATER ON 0938

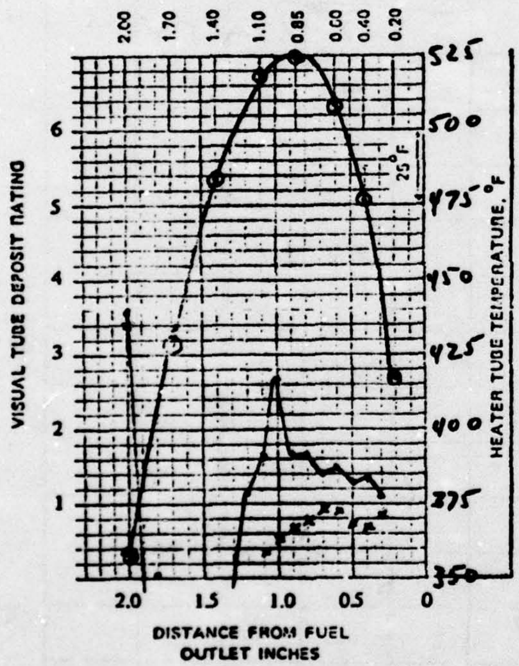
HEATER TUBE TEMPERATURE CONTROL (MAX.) 525 °F

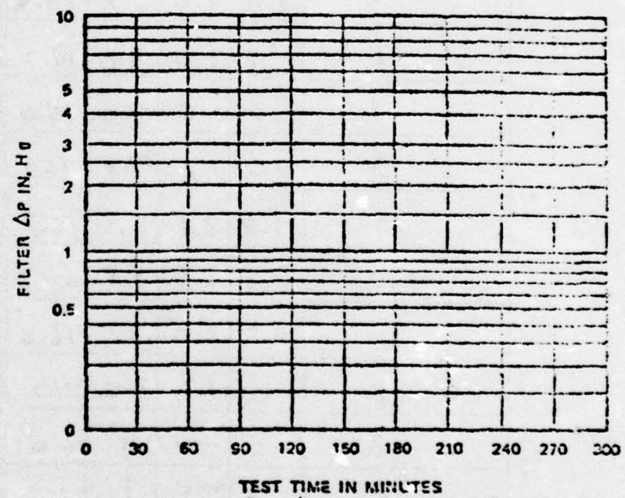
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	528
0.20	420
0.40	479
0.60	512
1.10	521
1.40	487
1.70	431
2.00	361
0.85	528

TEST TIME MINUTES	FILTER ΔP INCHES
0	0.0
30	0.0
60	0.0
90	0.0
120	0.0
150	0.0
180	
210	
240	
270	
300	

FILTER BYPASSED AT ―― MIN.





40 DROPS/SEC. 18.0

TEST FUEL CONSUMED 460 ml

DEPOSIT CODE:

<2-4 Streek

- 0 – NO VISIBLE DEPOSITS
- 1 – HAZE OR DULLING, NO COLOR
- 2 – BARELY VISIBLE DISCOLORATION
- 3 – LIGHT TAN
- 4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = A-0

TABLE D-10

SYNTHOIL 105 BLEND

TUBE RATING REPEATIBILITY AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE - 10-31-75

DATE TUBES RECEIVED 12/72 RUN #10

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW		(USED)	Tube Number	VISUAL					
	SPUN	SPOT	SPUN	SPOT			COLOR RATING			
0.3	4.8	7.3	8.1	10.8		Streak				
.4	3.7	4.3	6.7	13.7			<2	1.3 —	.55	
.5	2.0	2.2	7.2	13.0			4	1.1 —	.55	
.6	0.8	2.0	9.0	14.7						
.7	-0	-0	9.0	14.0			<2	1.2 —	0.7	
.8	-0	1.8	7.8	16.5			>4	1.0 —	0.7	
.9	0.9	2.1	6.3	16.7						
1.0	0.8	2.3	5.3	26.3						
.1	0.2	2.0	3.5	16.0						
.2	-0	1.0	-0	11.5						
.3	-0	-0		-0						
.4	-0	-0		-0						
.5	-0	1.2		-0						
.6	-0	0.8		-0						
.7	-0	0.1		-0						
.8	-0	1.7		0.2						
.9	-0	1.0	-0	-0						
2.0	31.7	35.7	34.0	35.8						
MAX. 2.1	45.0	45.7	45.2	46.5						

FIGURE 4-5
10-31-75

SYNTHOIL 105 BLEND
JFTOT D-8, D-9, D-10

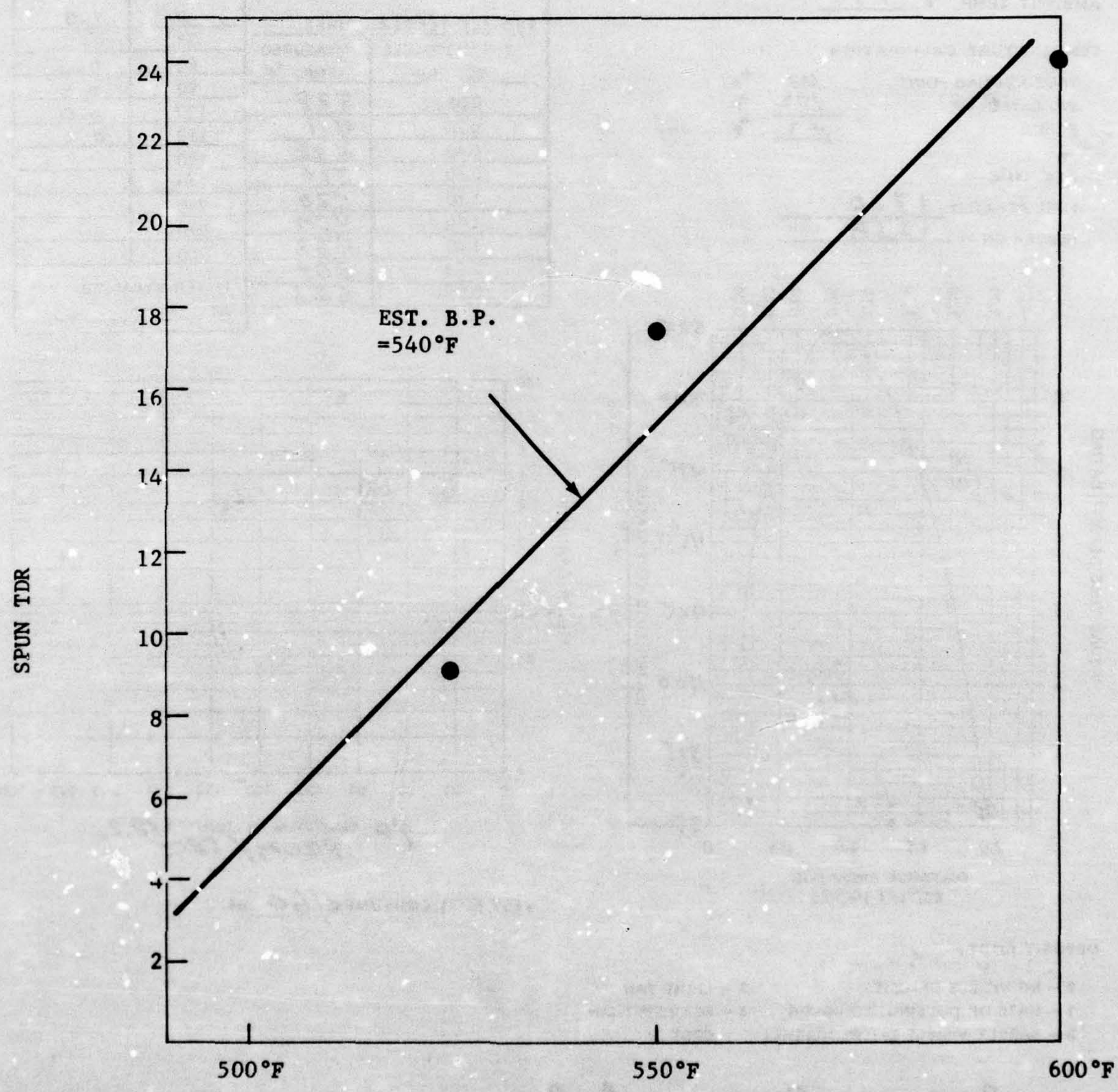


FIGURE D-11

ALCOR JET FUEL THERMAL OXIDATION TEST

DATE 10-31-75   400 PSI   TEST NO. D-11

FUEL DESCRIPTION SYNTHOIL 107 BLEND

RIG NO. ERR-1   OPERATOR W. DAVIS

AMBIENT TEMP., °F 77

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 1320

HEATER ON 1338

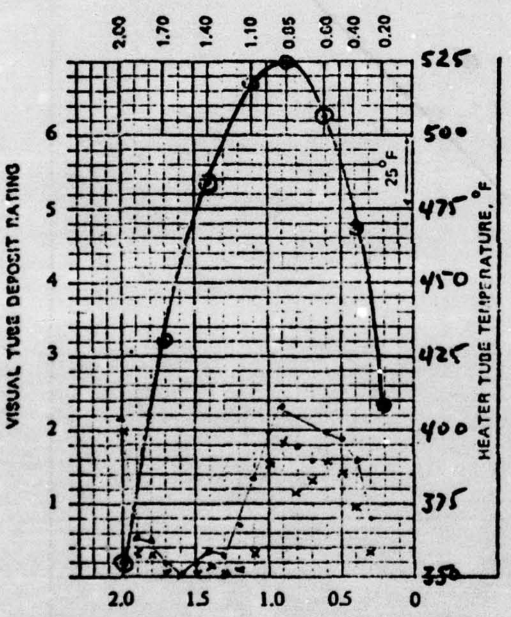
HEATER TUBE TEMPERATURE CONTROL (MAX.) 525 °F

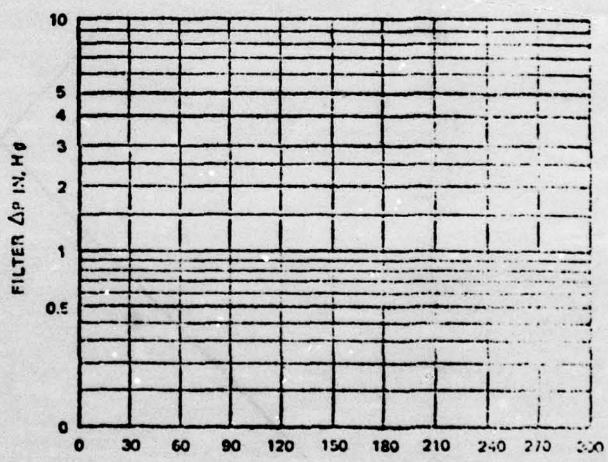
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	528
0.20	411
0.40	472
0.60	510
1.10	520
1.40	487
1.70	433
2.00	358
0.85	528

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.0
60	0.0
90	0.0
120	0.0
150	0.0
180	
210	
240	
270	
300	

FILTER BYPASSED AT — MIN.





40   18.2 DROPS / SECS

TEST FUEL CONSUMED 460 ml

DEPOSIT CODE:

<2-4 streak

0 – NO VISIBLE DEPOSITS
1 – HAZE OR DULLING, NO COLOR
2 – BARELY VISIBLE DISCOLORATION
3 – LIGHT TAN
4 – HEAVIER THAN CODE 3

REMARKS PREFILTER COLOR: A.0

TABLE D-11

SYNTHOIL 107 BLEND JET A

TUBE RATING REPEATIBILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE - 10-31-75

DATE TUBES RECEIVED 12/72 RUN # 11

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW SPUN	NEW SPOT	USED SPUN	USED SPOT	Tube Number VISUAL		COLOR	POSITION		
0.3	0.0	1.0	3.3	7.8		Strea[illegible]		1.25	-0.4	
.4	1.8	3.8	9.7	16.0			<2-4			
.5	0.6	1.7	14.1	18.4						
.6	0.9	3.0	15.9	19.0						
.7	-0	2.7	13.0	15.8			<2	1.0	-0.4	
.8		-0	11.8	18.0			<4	[illegible]	[illegible]	
.9		-0	18.2	23.1			>4	[illegible]	[illegible]	
1.0		0.3	15.0	19.8						
.1		1.1	3.4	13.7						
.2		0.8	0.9	7.0						
.3		0.0	0.2	1.7						
.4	1.0	1.2	1.8	2.8						
.5	-0	-0	0.2	1.7						
.6	-0	0.8	0.0	0.0						
.7	0.3	0.3	0.3	1.8						
.8	2.2	3.4	2.5	4.8						
.9	2.8	5.0	2.8	5.0						
2.0	35.6	37.4	18.9	21.7						
MAX. 2.1	45.2	46.5	45.0	46.2						

FIGURE D-12

ALCOR JET FUEL THERMAL OXIDATION TEST

DATE 11-3-75 TEST NO. D-12

400 PSI

FUEL DESCRIPTION Synthoil 10 7 Blend
RIG NO. ERE-1 OPERATOR W. Davis
AMBIENT TEMP., °F 77

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 0915
HEATER ON 0925

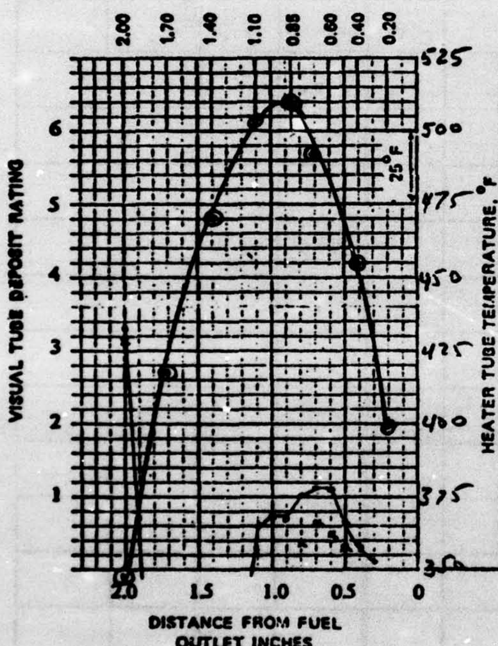
HEATER TUBE TEMPERATURE CONTROL (MAX.) 510 °F

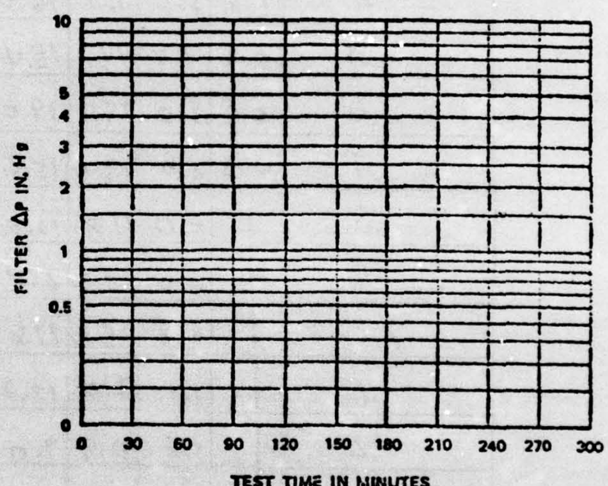
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	513
0.20	402
0.40	458
0.60	495
1.10	506
1.40	473
1.70	420
2.00	350
0.85	514

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.0
60	0.0
90	0.0
120	0.0
150	0.0
180	
210	
240	
270	
300	

FILTER BYPASSED AT ______ MIN.





40 Drops/Sec. 18.2

TEST FUEL CONSUMED ______ ml

DEPOSIT CODE: Streak <2-4

- 0 – NO VISIBLE DEPOSITS
- 1 – HAZE OR DULLING, NO COLOR
- 2 – BARELY VISIBLE DISCOLORATION
- <3 – LIGHT TAN
- 4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = AO

TABLE D-12

SYNTHOIL 107 BLEND JET A

TUBE RATING REPEATIBILITY AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE - 11-3-75

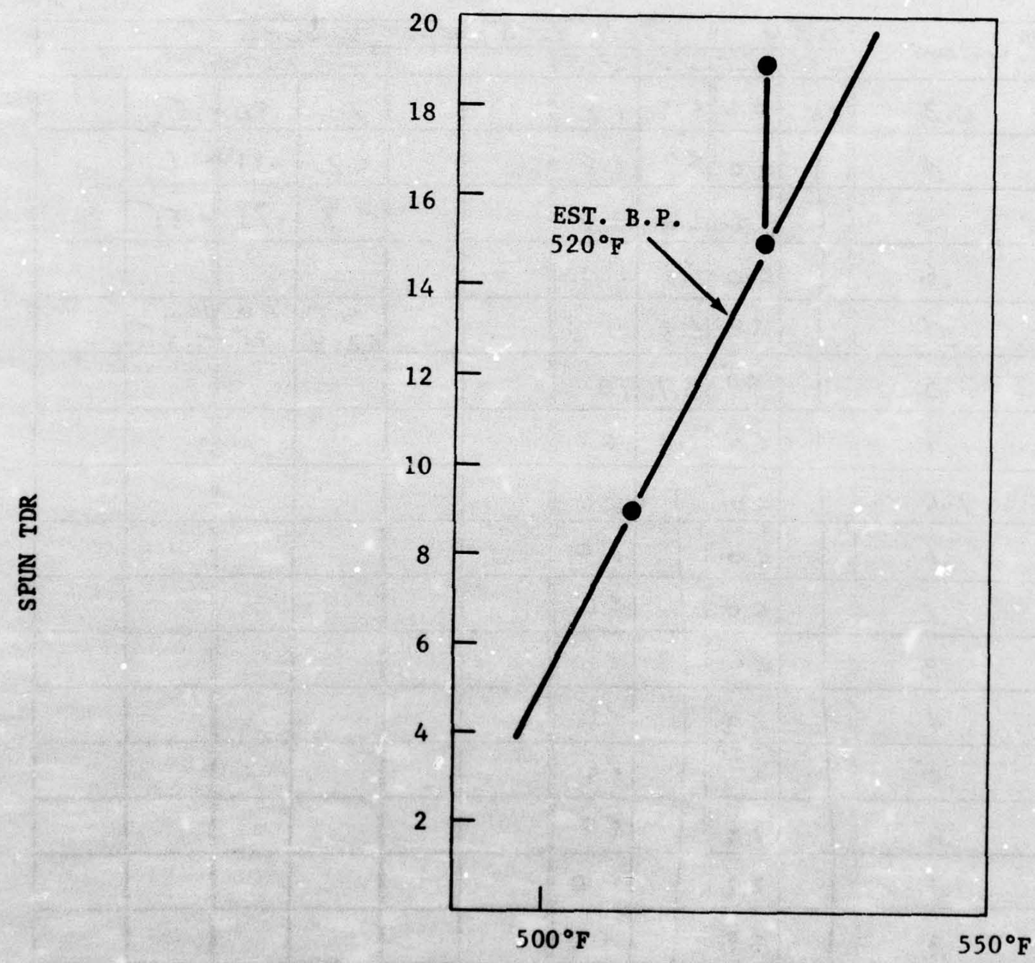
DATE TUBES RECEIVED 12/72 RUN #-12

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW SPUN	NEW SPOT	USED SPUN	USED SPOT	Tube Number		VISUAL COLOR	POSITION		
0.3	<0	0.2	<0	1.2			1	.90	.5	
.4		0.0	<0	2.8			<2	.55	.6	
.5		0.2	2.8	7.2			<3	.75	.55	
.6		0.0	5.8	11.1						
.7		<0	6.3	11.3			Streak <2-4	.95	.45	
.8		<0	3.7	10.0						
.9		<0	<0	6.3						
1.0		<0		6.8						
.1		<0		6.0						
.2		<0		<0						
.3		<0		<0						
.4		<0		<0						
.5		0.0		<0						
.6		1.2		<0						
.7		2.2		0.0						
.8		<0		<0						
.9		<0		<0						
2.0	0.3	1.0	31.8	33.3						
MAX.										

FIGURE 4-6
11-3-75

SYNTHOIL 107 BLEND
JFTOT D-11, D-12



DATE 11-18-75 | Figure D-13 400 PSI | TEST NO. D-13

FUEL DESCRIPTION Tosco 113 JP-4 Blend

RIG NO. ERE-1 OPERATOR W. DAVIS

AMBIENT TEMP., °F 77

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+ 3	°F

CLOCK TIME

FUEL AERATED 1255

HEATER ON 1310

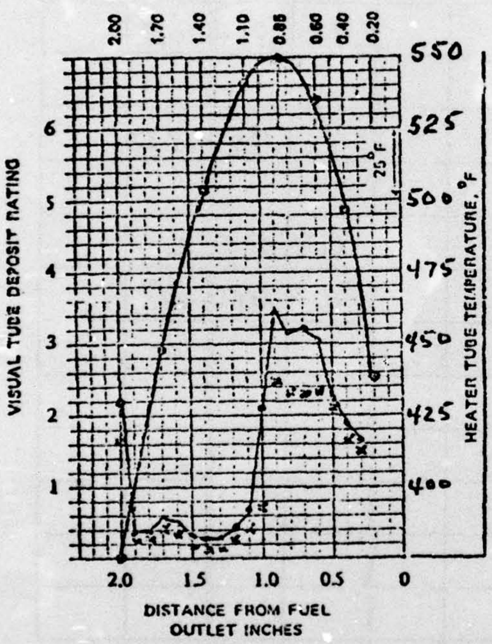
HEATER TUBE TEMPERATURE CONTROL (MAX.) 550 °F

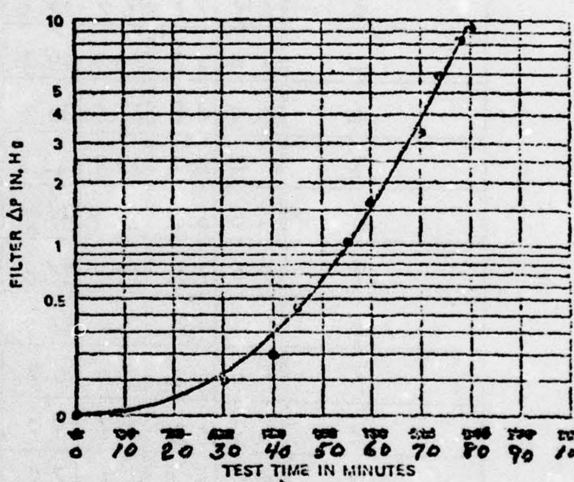
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	553
0.20	442
0.40	500
0.60	538
1.10	544
1.40	507
1.70	450
2.00	378
0.85	553

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.1
40	0.2
45	0.45
56	1.1
60	1.7
70	3.4
74	6.0
78	8.4
80	9.5

FILTER BYPASSED AT 81 MIN.





40 DROPS/SEC, 17.8

TEST FUEL CONSUMED 440 ml

DEPOSIT CODE: + 4 Streak

0 – NO VISIBLE DEPOSITS
1 – HAZE OR DULLING, NO COLOR
2 – BARELY VISIBLE DISCOLORATION
3 – LIGHT TAN
4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = B-2

Figure 7.– Suggested Data Sheet Chart

Table D-13

Tosco 113 JP-4 Blend

TUBE RATING REPEATIBILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE - 11/18/75

DATE TUBES RECEIVED 12/72 RUN # D-13

Tube Deposit Ratings, ALCOR Mark 8

	POSITION	NEW SPUN	NEW SPOT	USED SPUN	USED SPOT	Tube Number		VISUAL CODE	POSITION
	0.3	1.8	5.1	14.7	17.4			1	.95-.05
	.4	1.9	2.8	16.2	18.0				
	.5	1.0	1.2	20.9	24.3			4	.90-.30
	.6	0.3	1.8	23.6	30.3				
	.7	<0	0.2	22.9	32.0			STREAK	
	.8	<0	0.2	22.8	31.8			4	.95-.25
	.9	<0	1.8	24.7	34.0				
	1.0	<0	0.8	7.0	20.9				
	.1	1.0	4.2	4.0	6.7				
	.2	0.3	1.2	2.3	4.0				
	.3	<0	0.9	1.7	2.8				
	.4	<0	1.3	1.0	2.3				
	.5	0.2	2.0	1.6	3.0				
	.6	3.2	5.0	3.7	4.7				
	.7	3.7	5.0	4.0	5.0				
	.8	2.1	5.0	2.7	3.3				
	.9	1.7	3.3	2.2	3.3				
	2.0	36.8	38.0	16.3	22.0				
MAX.	2.1	45.2	46.7	45.2	46.8				

Figure D-14
Tosco 113 JP-4 Blend

ALCOR JET FUEL THERMAL OXIDATION TEST

DATE 11/19/75 40c '31 TEST NO. D-14

FUEL DESCRIPTION Tosco 113 JP-4 Blend
RIG NO. ERE-1 OPERATOR W. DAVIS
AMBIENT TEMP., °F. 77

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 0830
HEATER ON 0845

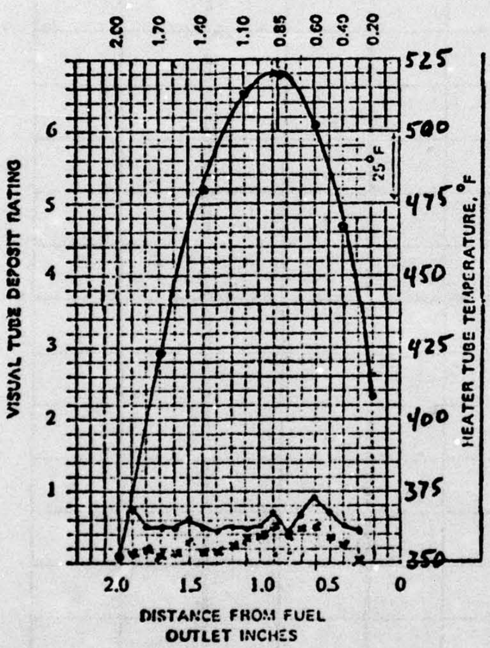
HEATER TUBE TEMPERATURE CONTROL (MAX.) 520 °F

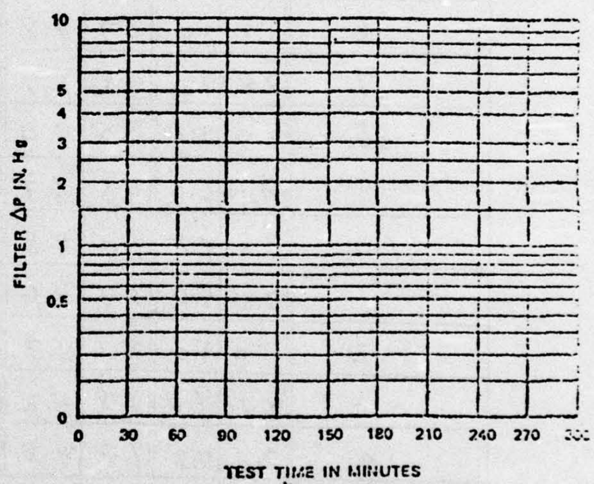
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	523
0.20	411
0.40	470
0.60	505
1.10	516
1.40	483
1.70	426
2.00	355
0.85	523

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.0
60	0.0
90	0.0
120	0.0
~~150~~/140	0.15
180/150	0.15
210	
240	
270	
300	

FILTER BYPASSED AT —— MIN.





40 DROPS/SEC. 17.0

TEST FUEL CONSUMED 460 ml

DEPOSIT CODE:

0 – NO VISIBLE DEPOSITS
1 – HAZE OR DULLING, NO COLOR
2 – BARELY VISIBLE DISCOLORATION
3 – LIGHT TAN
4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = A0

Table D-14

Tosco 113 JP-4 Blend

TUBE RATING REPEATIBILITY AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE - 11/19/75

DATE TUBES RECEIVED 12/72 RUN # D-[illegible]

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW		USED		Tube Number		VISUAL			
	SPUN	SPOT	SPUN	SPOT			CODE	POSITION		
0.3	0.0	1.5	0.2	4.5			<1	0.65		
.4	1.8	2.3	2.3	5.3						
.5	1.2	3.0	3.8	7.3						
.6	1.3	2.8	4.7	8.8						
.7	2.8	4.2	4.5	6.7						
.8	2.5	3.2	3.8	4.0						
.9	4.1	6.0	4.8	6.7						
1.0	3.8	4.7	4.0	4.8						
.1	3.3	5.0	3.4	4.6						
.2	2.0	5.0	2.1	4.7						
.3	1.7	4.0	1.8	4.2						
.4	2.1	4.8	1.8	4.8						
.5	3.0	5.2	2.9	6.1						
.6	2.0	4.9	1.9	4.6						
.7	1.3	4.8	1.0	4.9						
.8	2.3	6.0	1.9	5.2						
.9	2.0	8.5	1.4	7.9						
2.0	26.6	37.0	23.0							
MAX. 0.9	[illegible]	[illegible]	4.8							

FIGURE 4-7
11-21-75

TOSCO 113 BETA BLEND
JFTOT D-15, D-16, D-17

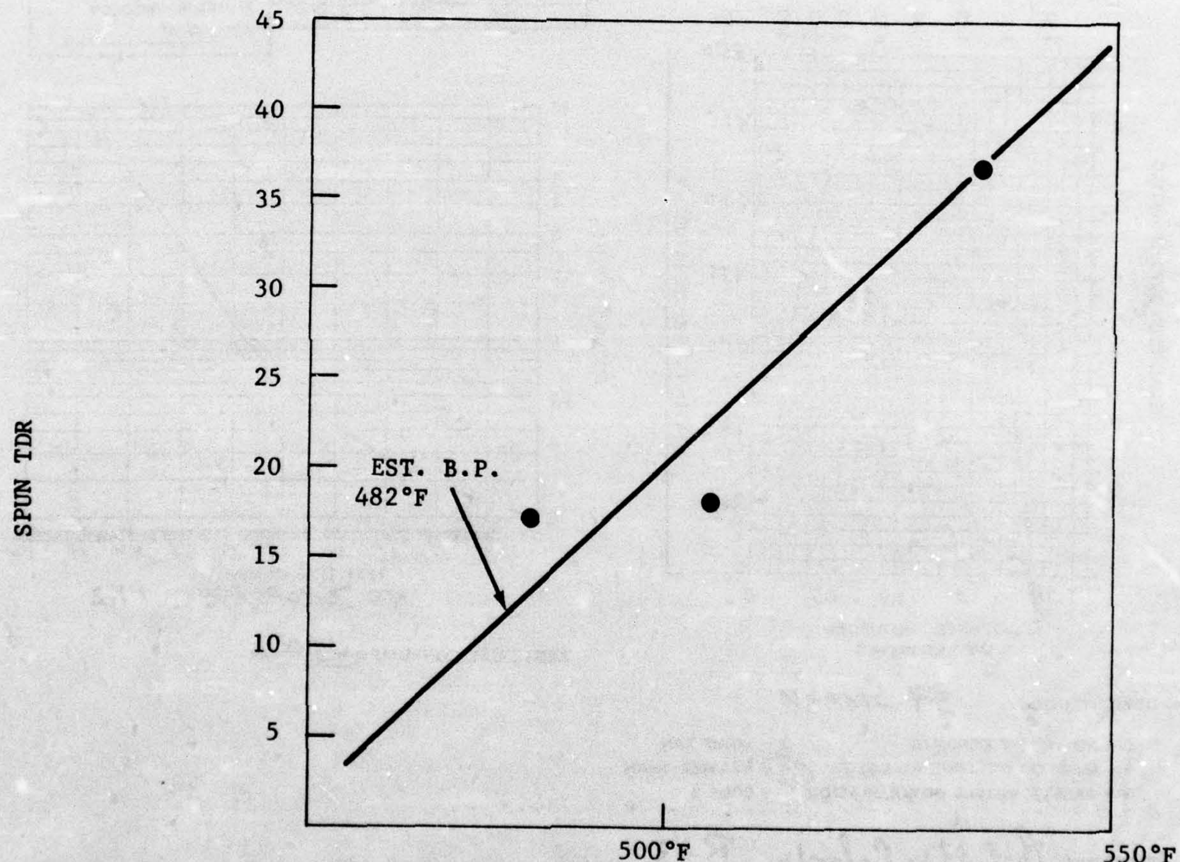


Figure D-15

DATE 11-20-75 | 400 PSI | TEST NO. D-15

FUEL DESCRIPTION Tosco 113 Jet A Blend

RIG NO. ERE-1 OPERATOR W. DAVI

AMBIENT TEMP., °F 77

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	453	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 1250

HEATER ON 1310

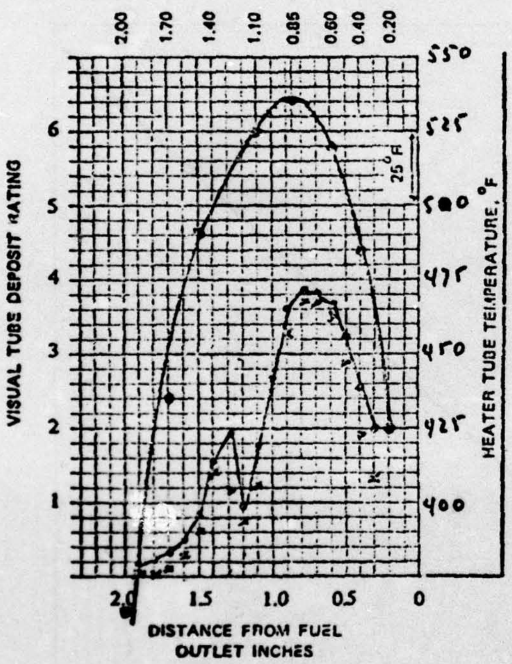
HEATER TUBE TEMPERATURE CONTROL (MAX.) 575 °F

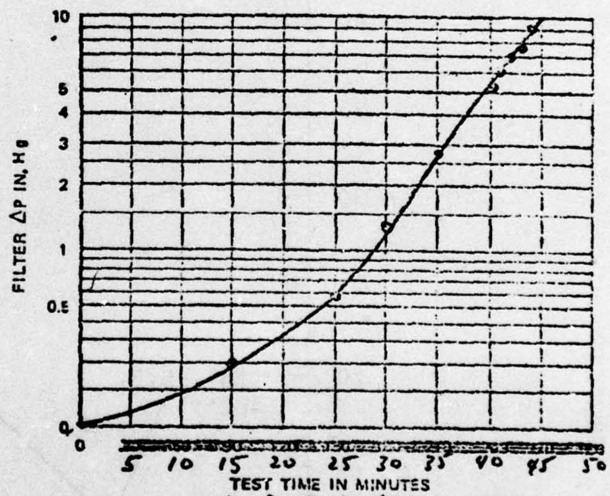
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	538
0.20	428
0.40	488
0.60	523
1.10	528
1.40	494
1.70	438
2.00	367
0.85	538

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
15	0.20
25	0.58
30	1.35
35	2.85
40	5.25
41	6.05
42	7.0
43	7.85
44	9.15

FILTER BYPASSED AT 44 MIN.





40 DROPS/SEC 17.2

TEST FUEL CONSUMED 450 ml

DEPOSIT CODE: #4 Streak

0 – NO VISIBLE DEPOSITS
1 – HAZE OR DULLING, NO COLOR
2 – BARELY VISIBLE DISCOLORATION
3 – LIGHT TAN
4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = B-3

Figure 7.– Suggested Data Sheet Chart

TABLE D-15
Tosco 113 Jet A Blend

TUBE RATING REPEATIBILITY AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE - 11-20-75

DATE TUBES RECEIVED 12/72 RUN # D-15

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW SPUN	NEW SPOT	USED SPUN	USED SPOT	Tube Number		VISUAL CODE	POSITION		
0.3	3.6	5.7	12.9	20.0			>2	1.5-	.1	
.4	2.2	4.5	19.0	25.8			3	1.3-	.15	
.5	0.4	2.8	28.8	32.2			4	1.0-	.45	
.6	1.3	3.9	35.7	36.4			STREAK >4	1.0-	.7	
.7	1.7	3.8	36.7	37.4						
.8	0.5	2.0	36.8	38.5			STREAK 3	0.5-	5.5	
.9	1.8	2.0	32.3	35.8						
1.0	<0	0.7	24.9	26.0						
.1	1.0	3.0	12.0	17.8						
.2	<0	<0	7.8	9.2						
.3	0.2	0.5	11.8	19.0						
.4	<0	0.2	14.3	15.3						
.5	<0	<0	6.1	8.0						
.6	<0	0.1	2.7	4.9						
.7	<0	0.2	1.0	3.0						
.8	<0	1.0	0.2	2.1						
.9	<0	0.0	0.2	1.2						
2.0	14.8	18.8	6.3	10.0						
MAX. 0.9	1.8		36.8	38.5						

AD-A036 190   EXXON RESEARCH AND ENGINEERING CO LINDEN N J GOVERNME--ETC   F/G 7/1
EVALUATION OF METHODS TO PRODUCE AVIATION TURBINE FUELS FROM SY--ETC(U)
MAY 76   C D KALFADELIS   F33615-74-C-2036
UNCLASSIFIED   EXXON/GRU.2PEA.76   AFAPL-TR-75-10-VOL-2   NL

4 OF 4
AD
A036190

END
DATE
FILMED
3-77

Figure D-16

400 PSI

DATE 11-21-75 TEST NO. D-16

FUEL DESCRIPTION Tosco 113 Jet A Blend

RIG NO. ERE-1 OPERATOR W. DAVIS

AMBIENT TEMP., °F 77

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 0840

HEATER ON 0900

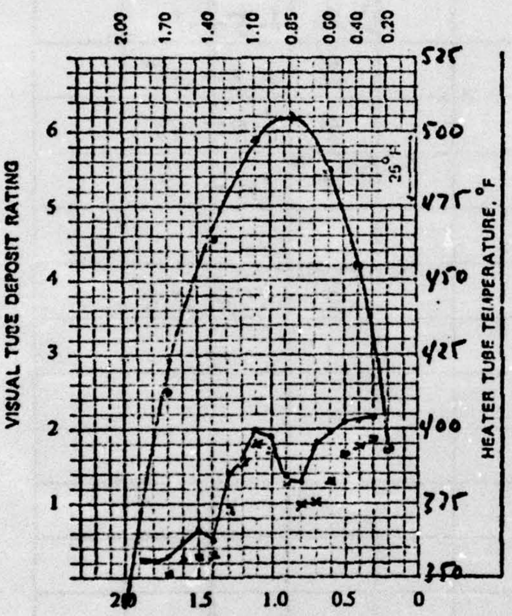
HEATER TUBE TEMPERATURE CONTROL (MAX.) 505 °F

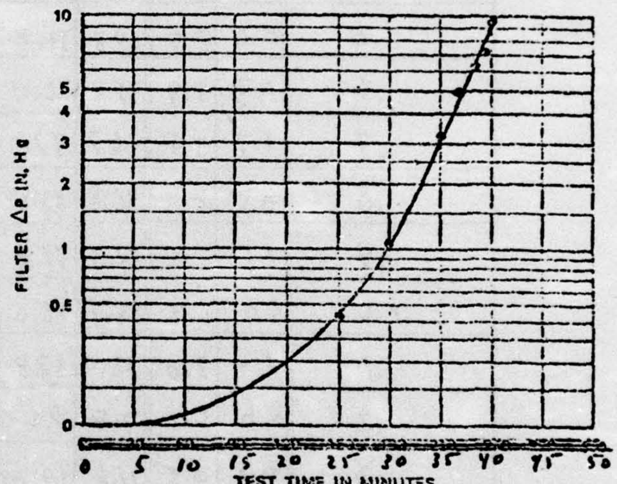
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	508
0.20	396
0.40	458
0.60	490
1.10	500
1.40	467
1.70	415
2.00	347
0.85	508

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.00
25	0.42
30	1.10
35	3.25
37	5.00
38	6.20
39	7.20
40	9.60

FILTER BYPASSED AT 40 MIN.





TEST FUEL CONSUMED 455 ml

DEPOSIT CODE: >4 Streak

0 – NO VISIBLE DEPOSITS
1 – HAZE OR DULLING, NO COLOR
2 – BARELY VISIBLE DISCOLORATION
3 – LIGHT TAN
4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = >B-2

Figure 7. – Suggested Data Sheet Chart

TABLE D-16

Tosco 113 Jet A Blend

TUBE RATING REPEATIBILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE - 11-21-75

DATE TUBES RECEIVED 12/72 RUN # D-16

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW		USED Tube Number				VISUAL			
	SPUN	SPOT	SPUN	SPOT			CODE	POSITION		
0.3	3.2	5.9	18.5	21.8			3	1.35	0.15	
.4	1.3	2.0	17.8	21.0			>4	0.15	0.0	
.5	2.1	3.5	16.5	20.8			>4	0.4	0.3	
.6	2.1	4.0	13.3	19.7						
.7	2.0	4.0	10.0	18.0			STREAK >4	1.4	0.3	
.8	1.5	3.0	9.8	12.7						
.9	1.3	3.1	12.7	13.7						
1.0	2.5	5.0	17.0	19.0						
.1	2.1	4.0	18.0	20.0						
.2	1.0	3.1	15.2	16.0						
.3	0.4	1.2	8.8	14.0						
.4	0.3	1.0	3.4	5.3						
.5	1.7	3.4	3.3	6.3						
.6	1.0	2.7	2.5	4.7						
.7	<0	0.0	0.5	3.0						
.8	<0	<0	<0	2.2						
.9	<0	<0	<0	2.2						
2.0	23.2	25.0	31.8	36.0						
MAX.										

Figure D-17

DATE 11-21-75 400 PSI TEST NO. D-17

FUEL DESCRIPTION Tosco 113 Jet A Blend

RIG NO. ERE-1 OPERATOR W. Davis

AMBIENT TEMP., °F 77°

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 1230

HEATER ON 1245

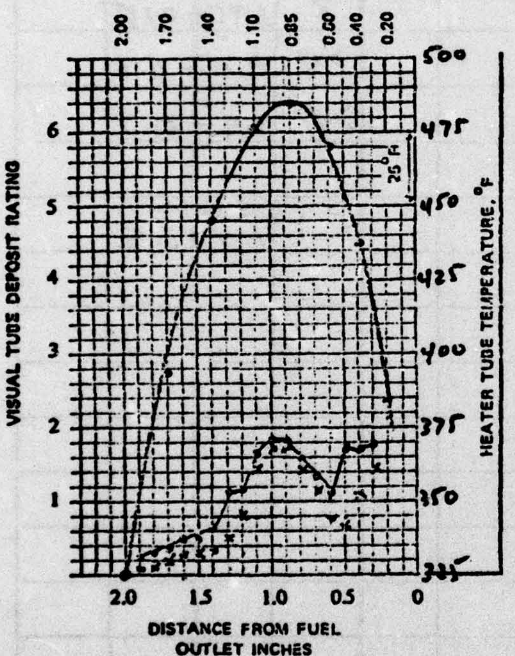
HEATER TUBE TEMPERATURE CONTROL (MAX.) 485 °F

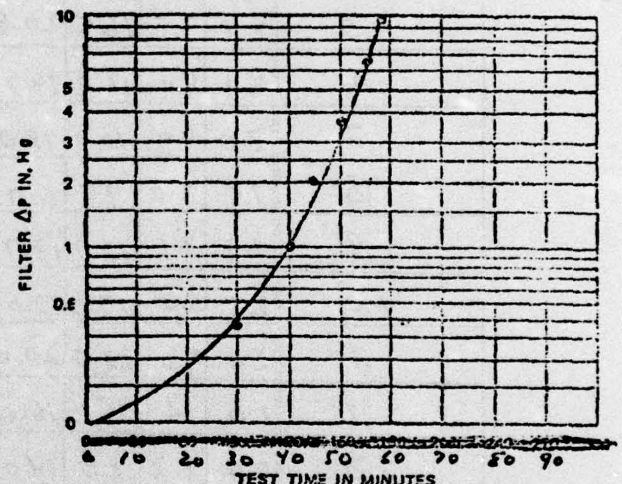
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	488
0.20	387
0.40	440
0.60	473
1.10	479
1.40	448
1.70	376
2.00	328
0.85	488

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.00
30	0.36
40	1.00
45	2.02
50	3.80
55	6.65
58	9.60

FILTER BYPASSED AT 58 MIN.





40 DROPS/SEC 18

TEST FUEL CONSUMED 440 ml

DEPOSIT CODE: >3 STREAK

0 – NO VISIBLE DEPOSITS
1 – HAZE OR DULLING, NO COLOR
2 – BARELY VISIBLE DISCOLORATION
3 – LIGHT TAN
4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = <B-3

Figure 7 – Suggested Data Sheet Chart

TABLE D-17

Tosco 113 Jet A Blend

TUBE RATING REPEATIBILITY AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE - 11-21-75

DATE TUBES RECEIVED 12/72 RUN # D-17

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW Tube Number SPUN	NEW SPOT	USED SPUN	USED SPOT			VISUAL CODE	POSITION		
0.3	1.1	3.6	14.2	17.8			2	1.2 -	.25	
.4	1.2	3.0	10.9	16.8			3	1.15 -	.3	
.5	1.0	3.2	6.8	16.9			>4	.2 -	0	
.6	1.3	3.3	7.5	11.0						
.7	0.8	2.2	11.7	13.7			STREAK			
.8	0.0	1.1	14.2	16.0			>3	1.45 ±	.05	
.9	1.0	3.0	17.2	18.0						
1.0	0.3	3.0	16.9	18.2						
.1	1.2	3.6	14.2	16.3						
.2	0.5	2.0	8.0	11.9						
.3	1.3	4.1	4.9	11.2						
.4	1.8	3.8	3.3	6.1						
.5	1.9	4.9	2.8	5.0						
.6	1.9	4.2	2.5	5.0						
.7	2.3	3.2	2.0	3.7						
.8	0.3	2.0	1.0	3.0						
.9	<.0	2.0	0.7	2.2						
2.0	7.0	13.0	36.0	38.5						
MAX.	2.3	4.9	17.2	18.2						

FIGURE 4-8
11-19-75

TOSCO 113 ALPHA BLEND
JFTOT D-13, D-14

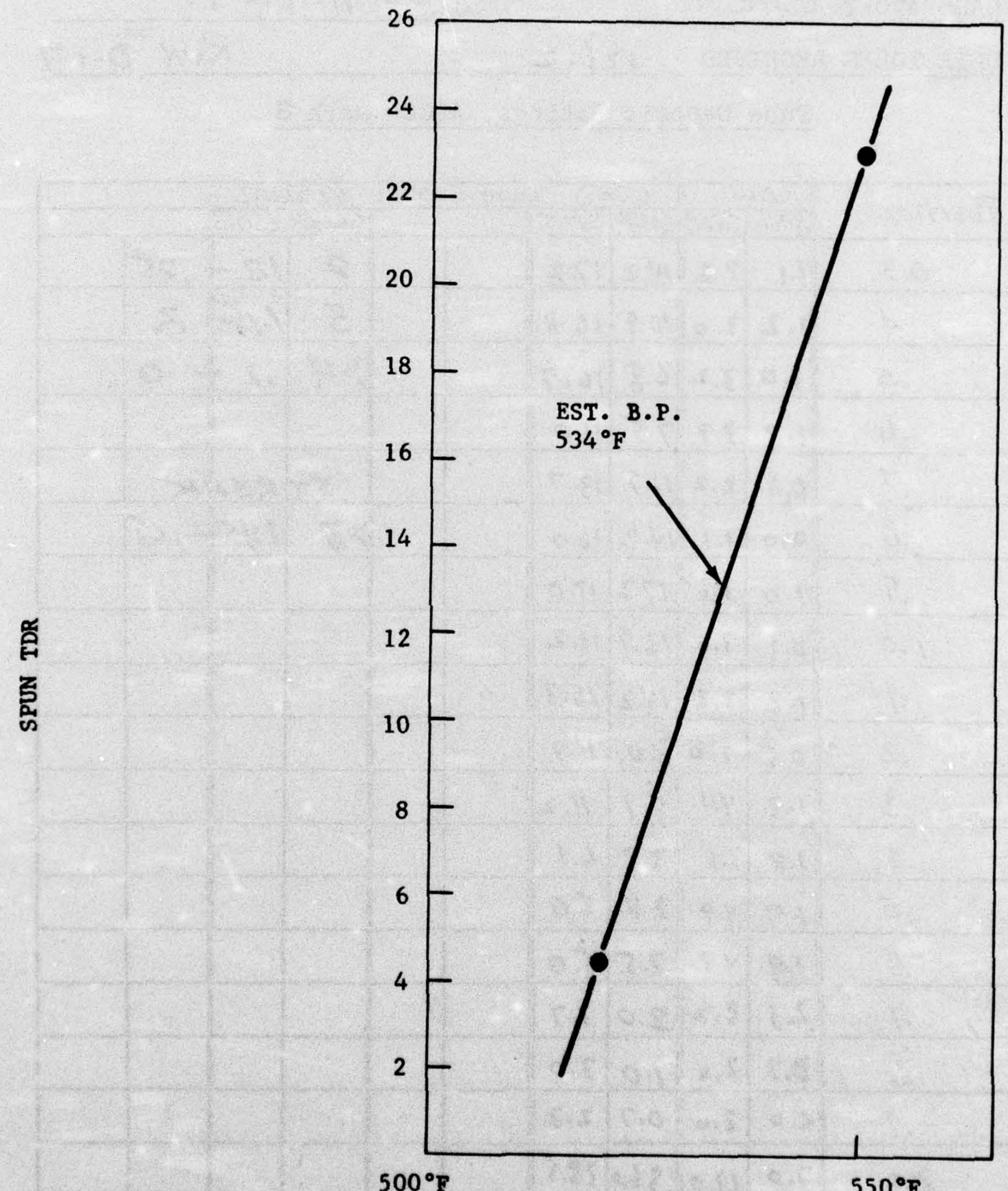


Figure D-18

ALCOR JET FUEL THERMAL OXIDATION TEST

DATE ______________ 400 PSI TEST NO. D - 18

FUEL DESCRIPTION SYNTHOIL 203 FINAL BLEND

RIG NO. ERE-1 OPERATOR W. Davis

AMBIENT TEMP., °F 77

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 1250

HEATER ON 1300

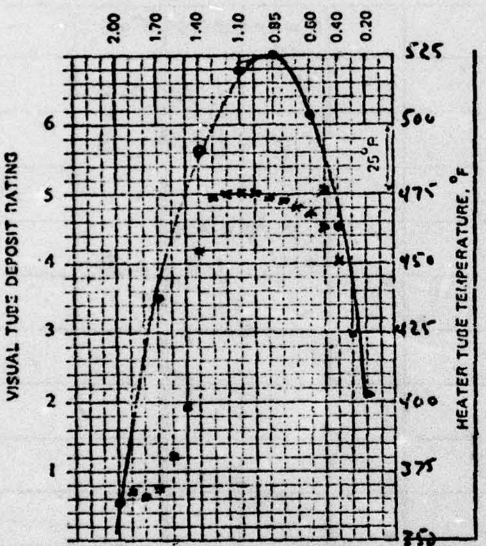
HEATER TUBE TEMPERATURE CONTROL (MAX.) 525 °F

PROFILE TEMPERATURES

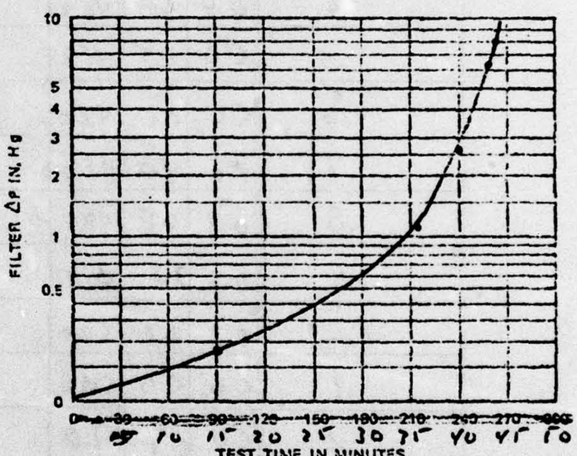
THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	528
0.20	406
0.40	466
0.60	507
1.10	521
1.40	490
1.70	440
2.00	366
0.85	528

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
15	0.16
36	1.10
40	2.52
43	6.2
44	8.0
180	
210	
240	
270	
300	

FILTER BYPASSED AT 44.5 MIN.



DISTANCE FROM FUEL OUTLET INCHES



40 DROPS/SEC 19

TEST FUEL CONSUMED 450 ml

DEPOSIT CODE: >4 STREAK

0 – NO VISIBLE DEPOSITS
1 – HAZE OR DULLING, NO COLOR
2 – BARELY VISIBLE DISCOLORATION
3 – LIGHT TAN
4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = B-1

Table D-18

Synthoil 203 Jet A Final Blend

TUBE RATING REPEATIBILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE - 11-24-75

DATE TUBES RECEIVED 12/72 RUN # 18

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW SPUN	NEW SPOT	USED SPUN	USED SPOT			VISUAL COLOR	POSITION		
0.3	3.2	5.1	29.8				COPPER	FINISH	COAT	
.4	0.8	2.0	40.2				4	1.6-	0.2	
.5	<0	2.5	45.2				<4	1.45-	0.3	
.6	<0	2.8	47.0							
.7	1.0	4.0	48.0				STREAK +4	1.8-	0.3	
.8	0.3	2.5	48.8							
.9	0.8	3.3	48.4							
1.0	0.3	2.1	50.0							
.1	<0	<0	50.0							
.2	<0	0.1	50.0							
.3	<0	1.2	49.8							
.4	0.7	2.0	41.7							
.5	0.7	2.0	18.8							
.6	0.7	1.7	12.2							
.7	<0	1.0	7.4							
.8	0.0	1.0	6.2							
.9	1.0	3.0	7.0							
2.0	32.5	35.8	26.0	31.2						
MAX.	0.8		50.0							

Figure D-19

DATE 11/25/75 400 PSI TEST NO. D-19

FUEL DESCRIPTION Synthetic 20% Final Blend
RIG NO. ERE-1 OPERATOR W. Davis
AMBIENT TEMP., °F 77

TEMPERATURE CALIBRATION

TRUE MELTING POINT 4[illegible] °F
INDICATED MP 452 °F
ERROR +3 °F

CLOCK TIME

FUEL AERATED 0835
HEATER ON 0850

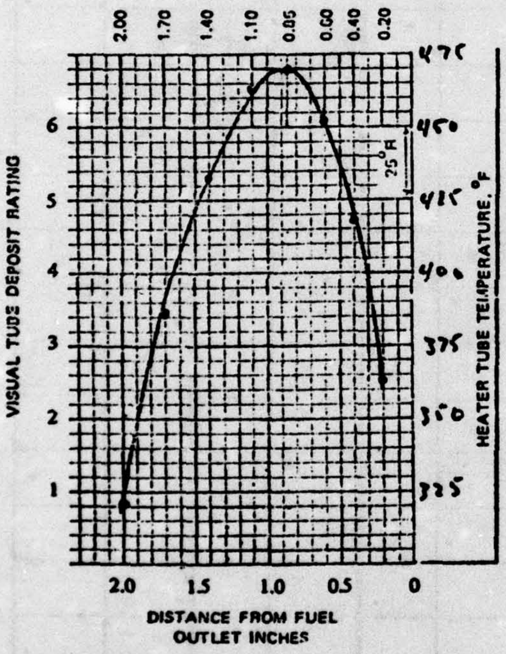
HEATER TUBE TEMPERATURE CONTROL (MAX.) 470 °F

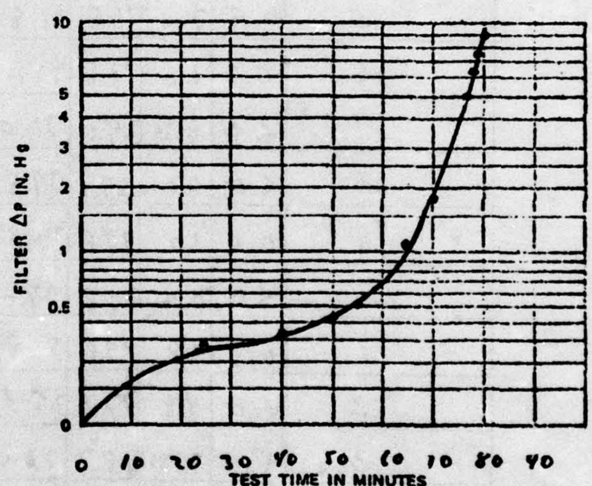
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	473
0.20	366
0.40	421
0.60	455
1.10	466
1.40	435
1.70	389
2.00	323
0.85	473

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
25	0.28
40	0.32
50	0.42
55	0.50
65	1.10
70	1.80
77	5.00
78	6.20
79	7.40
80	8.90

FILTER BYPASSED AT 80 MIN.





40 DROPS/SEC 19

TEST FUEL CONSUMED 450 ml

DEPOSIT CODE: >4 STREAK

0 – NO VISIBLE DEPOSITS
1 – HAZE OR DULLING, NO COLOR
2 – BARELY VISIBLE DISCOLORATION
3 – LIGHT TAN
4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = B-0

Table D-19

Synthoil 203 Jet A Final Blend

TUBE RATING REPEATIBILITY AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE - 11-25-75

DATE TUBES RECEIVED 12/72 RUN # D-19

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW SPUN	NEW SPOT	USED SPUN	USED SPOT	Tube Number VISUAL		CODE POSITION			
0.3	<0	<0	0.0	2.5						
.4	<0	0.4	7.9	11.8			3	1.35	± 0.4	
.5	0.9	2.0	16.8	21.8			4	1.3	± 0.4	
.6	0.2	1.0	22.8	29.0			K4 COPPER	1.1	- 0.[illegible]	
.7	<0	0.0	29.0	36.0			Stripe			
.8	<0	0.0	33.1	39.8			K4	1.4	± 0.3	
.9	0.0	1.0	34.8	40.2						
1.0	<0	0.4	30.8	39.0						
.1	0.3	1.8	19.8	31.8						
.2	4.0	4.8	17.2	25.8						
.3	5.1	7.7	18.7	20.0						
.4	4.8	7.7	15.2	15.5						
.5	4.2	7.5	10.0	12.2						
.6	3.5	5.6	6.6	7.2						
.7	2.4	3.8	4.3	6.8						
.8	3.3	5.8	7.0	9.9						
.9	3.9	6.2	8.9	9.2						
2.0	20.0	22.1	18.8	20.2						
MAX.	5.1	7.7	34.8							

Figure D-20

ALCOR JET FUEL THERMAL OXIDATION TEST

DATE 11/25/75 400 PSI TEST NO. D-20

FUEL DESCRIPTION Synthoil 203 Final Blend
RIG NO. ERE-1 OPERATOR W. Davis
AMBIENT TEMP., °F 77

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 1320
HEATER ON 1335

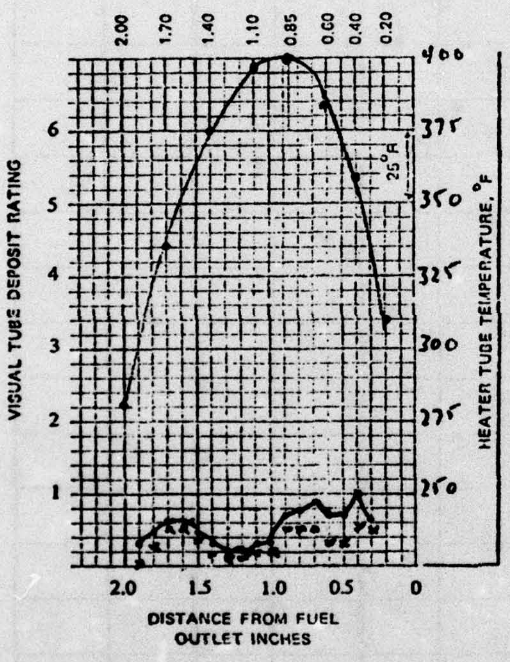
HEATER TUBE TEMPERATURE CONTROL (MAX) 400 °F

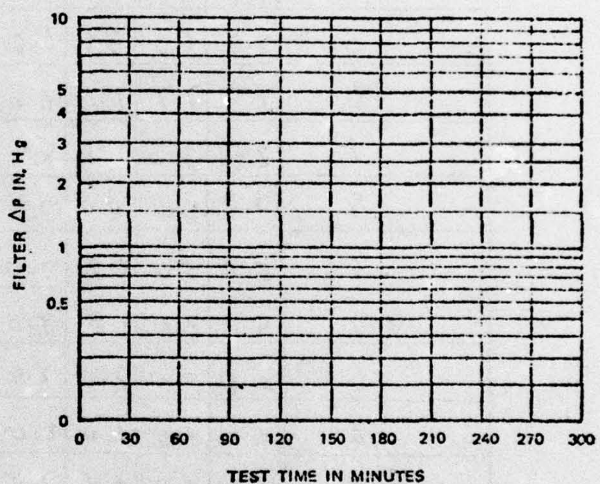
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	403
0.20	313
0.40	362
0.60	387
1.10	400
1.40	378
1.70	338
2.00	284
0.85	403

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.28
60	0.28
90	
120	
150	
180	
210	
240	
270	
300	

FILTER BYPASSED AT ——— MIN.





40 DROPS/SEC 18.8

TEST FUEL CONSUMED 480 ml

DEPOSIT CODE:

0 – NO VISIBLE DEPOSITS
<1 – HAZE OR DULLING, NO COLOR
2 – BARELY VISIBLE DISCOLORATION
3 – LIGHT TAN
4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = A.0

Table D-20

Synthoil 203 Jet A Blend

TUBE RATING REPEATIBILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE - 11/25/75

DATE TUBES RECEIVED 12/72 RUN # D-20

Tube Deposit Ratings, ALCOR Mark 8

Position	NEW		USED	Tube Number			VISUAL			
	SPUN	SPOT	SPUN	SPOT			CODE	POSITION		
0.3	4.3	8.2	5.0	6.2						
.4	4.8	8.7	5.7	10.0						
.5	2.2	6.0	3.3	6.8			<1	0.9		
.6	1.8	3.3	3.2	6.8						
.7	2.7	3.0	4.8	8.9						
.8	2.3	4.0	4.9	7.8						
.9	3.0	3.0	5.2	7.0						
1.0	<0	2.1	1.8	3.0						
.1	0.0	0.0	2.0	2.9						
.2	<0	1.0	1.0	2.0						
.3	<0	<0	0.6	1.5						
.4	0.0	1.8	1.9	3.1						
.5	1.2	2.7	3.8	4.7						
.6	1.2	2.4	5.0	6.0						
.7	1.2	2.7	4.5	6.0						
.8	<0	0.3	2.5	4.4						
.9	<0	0.4	0.0	2.8						
2.0	33.0	36.0	9.0	15.5						
MAX.	3.0		5.2							

FIGURE 4-9
11-25-75

SYNTHOIL 203 FINAL BLEND
JFTOT D-18, D-19, D-20

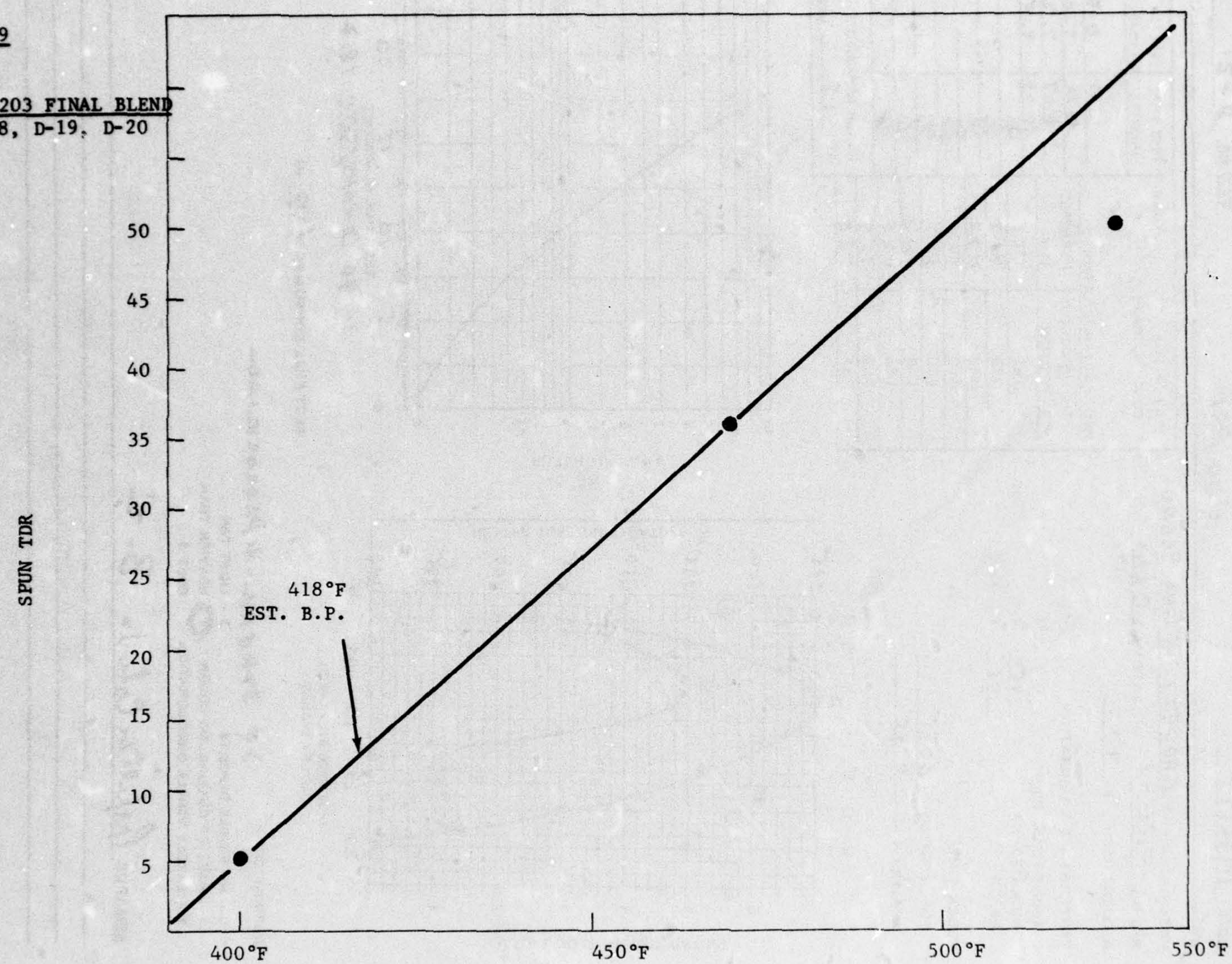


Figure D-21

DATE 11/26/75 | 400 PSI | TEST NO. D-21

FUEL DESCRIPTION GARRETT 115 FINAL BLEND

RIG NO. ERE-1 OPERATOR W. DAVIS

AMBIENT TEMP., °F 77

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 0925

HEATER ON 0945

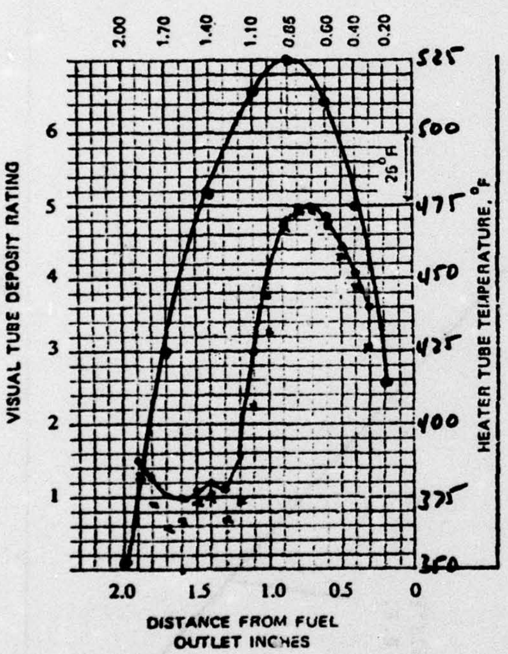
HEATER TUBE TEMPERATURE CONTROL (MAX.) 525 °F

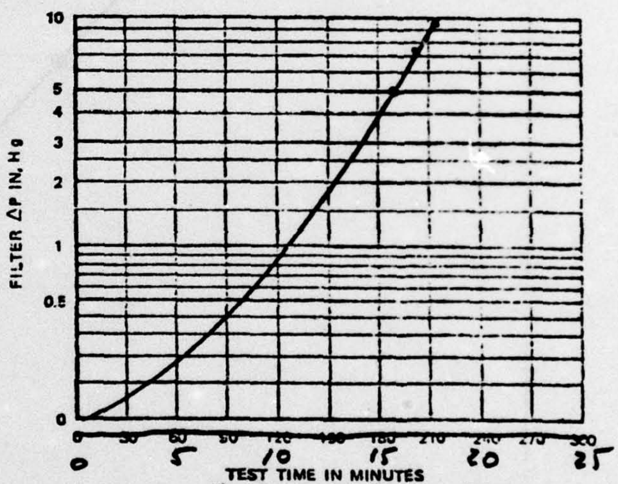
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	528
0.20	417
0.40	478
0.60	514
1.10	517
1.40	482
1.70	428
2.00	355
0.85	528

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
16	5.0
17	7.2
18	9.5

FILTER BYPASSED AT 18 MIN.





40 DROPS/SEC 18.2

TEST FUEL CONSUMED 450 ml

DEPOSIT CODE: >4 STREAK + PEACOCKING

- 0 – NO VISIBLE DEPOSITS
- 1 – HAZE OR DULLING, NO COLOR
- 2 – BARELY VISIBLE DISCOLORATION
- 3 – LIGHT TAN
- 4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = B-2+

Table D-21

Garrett 115 Jet A Final Blend

TUBE RATING REPEATIBILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE - 11-26-75

DATE TUBES RECEIVED 12/72 RUN # D-21

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW		USED		Tube Number		VISUAL			
	SPUN	SPOT	SPUN	SPOT			CODE	POSITION		
0.3	<0	1.5	30.3	36.0			PEACOCK	1.1 -	0.9	
.4		1.1	39.0	40.2			3	1.15 -	0.15	
.5		2.0	43.2	44.0			>4	0.95 -	0.3	
.6		2.0	47.5	48.2						
.7		0.2	49.2	49.8						
.8		0.3	49.2	49.8			STREAK >4	1.2 -	0.3	
.9		<0	45.0	47.0						
1.0	<0	0.7	32.3	37.7						
.1	2.8	3.9	22.2	29.8						
.2	1.6	3.0	9.7	15.6						
.3	<0	1.9	8.7	11.1						
.4	<0	0.2	10.2	12.0						
.5	<0	1.7	9.7	10.8						
.6	<0	1.0	6.8	10.0						
.7	0.2	3.1	5.9	10.0						
.8	0.2	3.0	8.9	12.2						
.9	1.3	3.4	13.0	15.0						
2.0	11.0	14.0	17.8	21.0						
MAX	2.8		49.2							

Figure D-22

DATE 11-26-75 400 PSI TEST NO. D-22

FUEL DESCRIPTION GARRETT III FINAL BLEND
RIG NO. ERE-1 OPERATOR W. DAVIS
AMBIENT TEMP., °F 77

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 1320
HEATER ON 1330

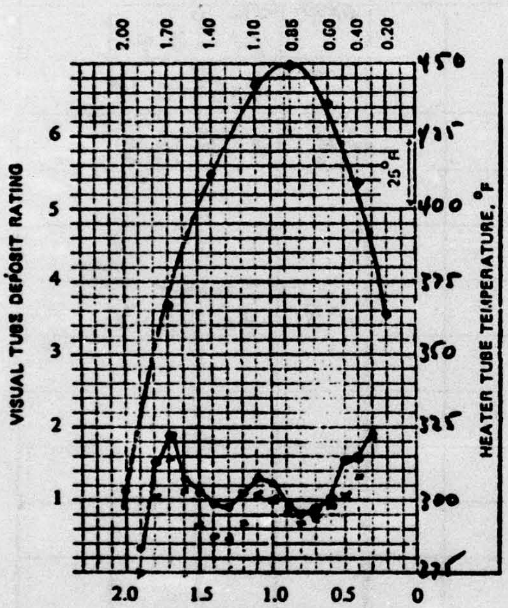
HEATER TUBE TEMPERATURE CONTROL (MAX.) 450 °F

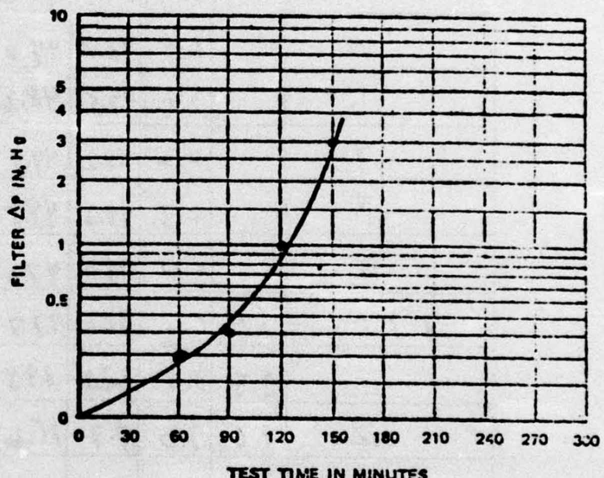
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	453
0.20	367
0.40	412
0.60	439
1.10	445
1.40	415
1.70	369
2.00	307
0.85	453

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.0
60	0.2
90	0.3
120	1.0
150	3.0
180	
210	
240	
270	
300	

FILTER BYPASSED AT — MIN.





DROPS/SEC

TEST FUEL CONSUMED 450 ml

DEPOSIT CODE: >4 STREAK

0 – NO VISIBLE DEPOSITS
1 – HAZE OR DULLING, NO COLOR
2 – BARELY VISIBLE DISCOLORATION
3 – LIGHT TAN
4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = B-2

Table D-22

Garrett 115 Jet A Final Blend

TUBE RATING REPEATIBILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE - 11/26/75

DATE TUBES RECEIVED 12/22 RUN # D-22

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW		USED		Tube Number		VISUAL			
	SPUN	SPOT	SPUN	SPOT			CODE	POSITION		
0.3	<0	1.0	18.8	19.0			2	1.85 –	0.2	
.4		1.8	13.0	16.0			3	1.75 –	0.25	
.5		0.8	10.2	15.5			< 4	1.65 –	0.3	
.6		0.6	9.0	9.9			4	0.3 –	0.0	
.7		1.2	7.6	9.0			5+	[illegible]		
.8		0.2	6.8	8.0			> 4	1.8 –	0.2	
.9	<0	1.7	8.1	8.9						
1.0	0.2	5.0	10.0	12.2						
.1	0.2	3.2	10.4	13.0						
.2	<0	3.8	6.8	11.0						
.3	<0	2.8	4.5	8.8						
.4	<0	2.0	5.0	9.3						
.5	<0	2.2	6.5	10.9						
.6	0.0	4.0	11.2	16.8						
.7	<0	1.5	15.8	18.9						
.8	<0	0.8	10.2	15.0						
.9	<0	0.0	<0	3.4						
2.0	22.5	29.2	28.2	30.8						
MAX.	0.2		15.8	18.9						

FIGURE 4-10
11-26-75

GARRETT 115 FINAL BLEND
JFTOT D-21, D-22

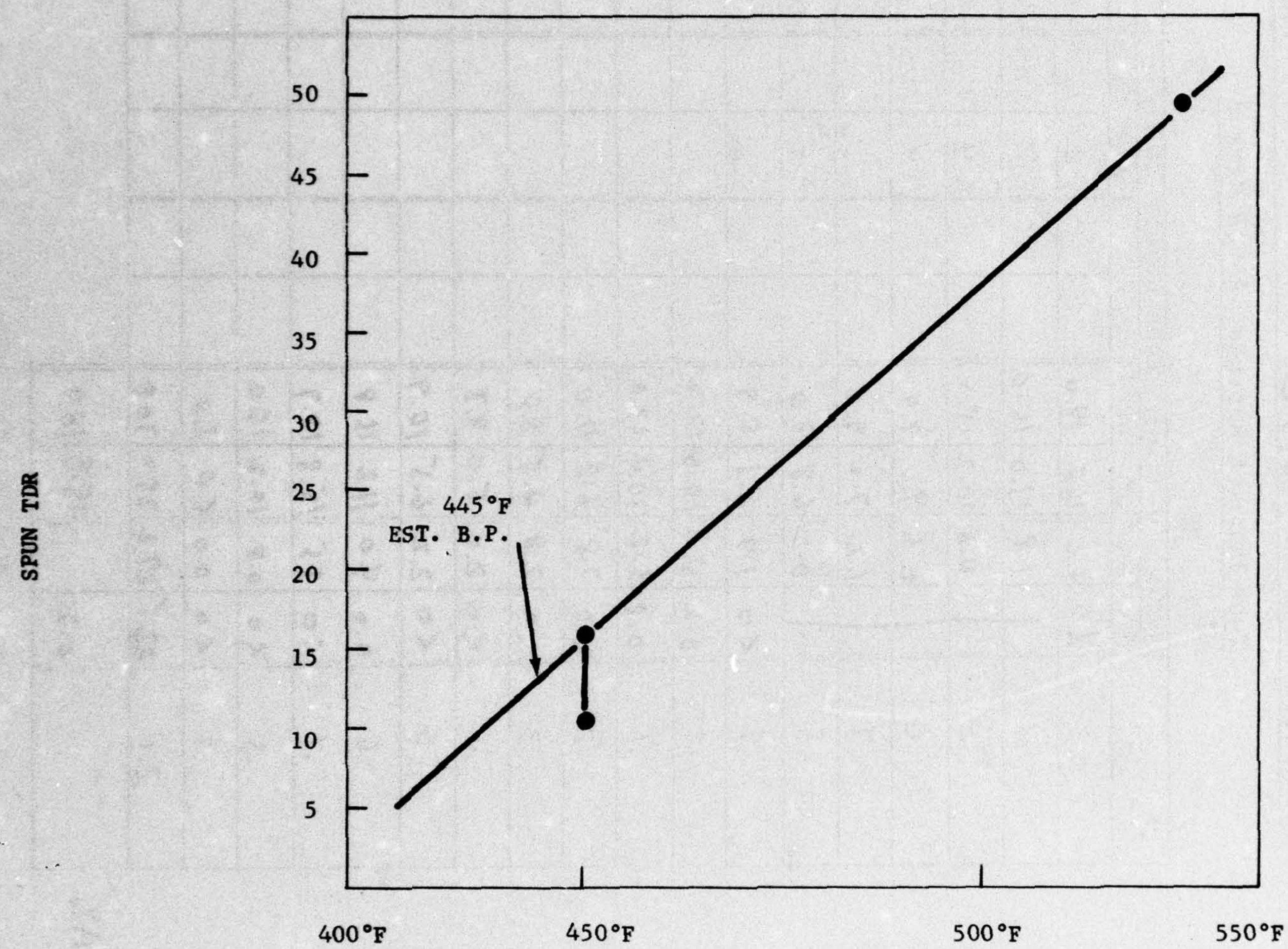


Figure D-23

DATE 12-1-75 400 PSI TEST NO. D-23

FUEL DESCRIPTION Paraho III Final Blend

RIG NO. ERE-1 OPERATOR W. Davis

AMBIENT TEMP., °F 77

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 0845

HEATER ON 0905

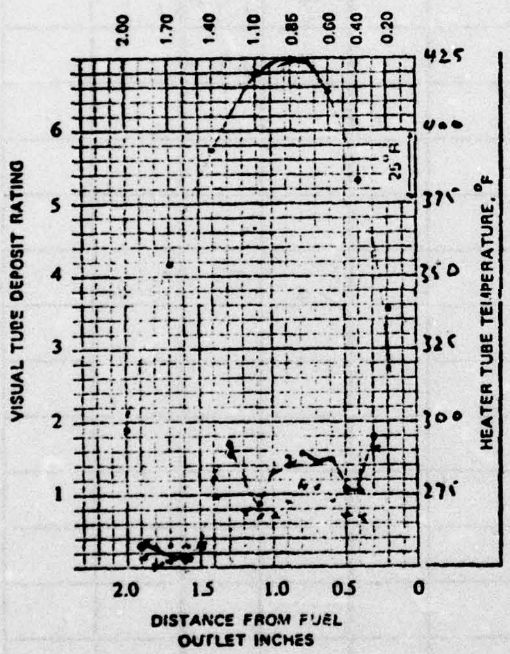
HEATER TUBE TEMPERATURE CONTROL (MAX.) 425 °F

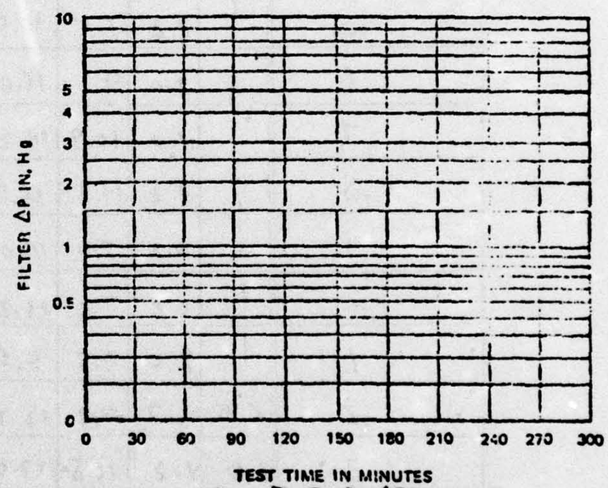
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	428
0.20	341
0.40	386
0.60	416
1.10	423
1.40	396
1.70	357
2.00	300
0.85	428

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.0
60	0.0
90	0.0
120	0.0
150	
180	
210	
240	
270	
300	

FILTER BYPASSED AT — MIN.





40 DROPS/SEC 18

TEST FUEL CONSUMED 460 ml

DEPOSIT CODE:

0 – NO VISIBLE DEPOSITS
1 – HAZE OR DULLING, NO COLOR
2 – BARELY VISIBLE DISCOLORATION
3 – LIGHT TAN
4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = A-1

Table D-23

Paraho 111 Jet A Final Blend

TUBE RATING REPEATIBILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE - 12-1-75

DATE TUBES RECEIVED 12/72 RUN # D-23

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW SPUN	NEW SPOT	USED SPUN	USED SPOT	Tube Number		VISUAL CODE	POSITION		
0.3	<0	2.2	16.2	15.0			3	1.35	[illegible]	
.4		3.0	6.8	10.2			4	1.3	0.3	
.5		3.2	7.4	10.8						
.6		2.0	9.1	15.0						
.7		1.0	10.9	14.2						
.8		1.2	11.1	15.7			[illegible] >4	[illegible]	0.2	
.9		0.2	8.9	14.0						
1.0		0.2	7.2	13.2						
.1		2.0	7.3	8.5						
.2	<0	2.7	9.7	12.2						
.3	1.0	1.2	11.8	17.0						
.4	2.0	3.7	9.0	12.2						
.5	2.0	2.2	3.0	3.0						
.6	0.2	0.9	1.0	1.6						
.7	0.0	1.3	0.9	1.7						
.8	0.2	1.6	0.0	2.3						
.9	0.9	2.0	1.7	3.0						
2.0	7.3	12.2	10.2	14.0						
MAX.	2.0		16.8	17.0						

FIGURE 4-11
12-1-75

PARAHO III FINAL BLEND
D-23 JFTOT

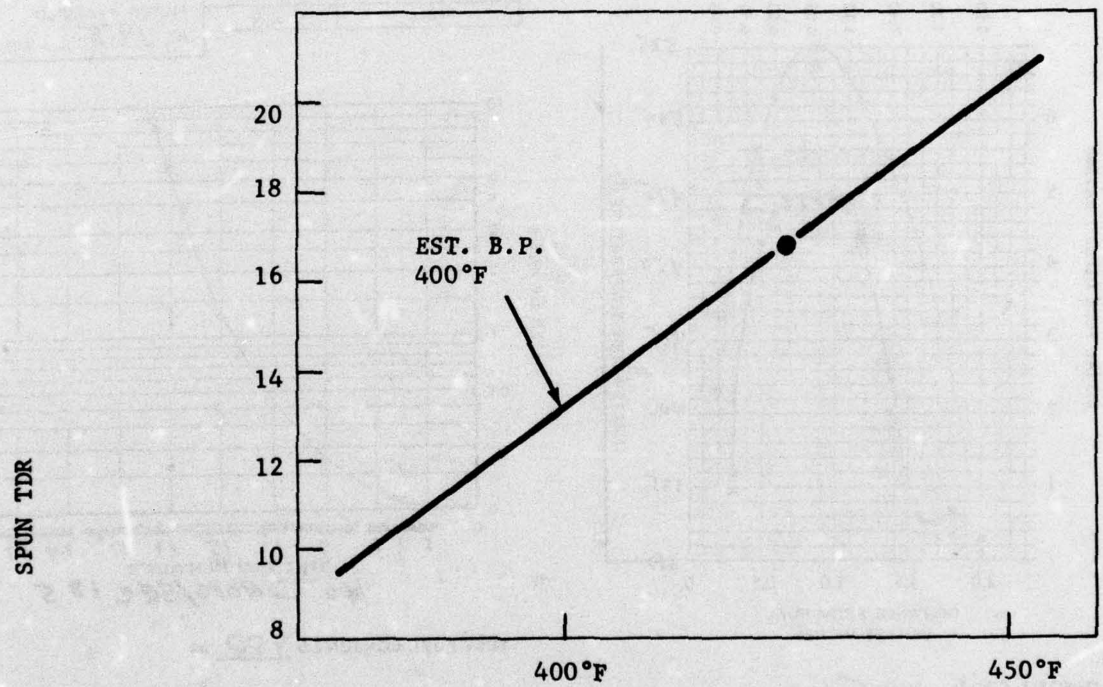


Figure D-24

DATE 12-8-75 400 PSI TEST NO. D-24

FUEL DESCRIPTION SYNTHOIL 202 FINAL BLEND

RIG NO. ERE-1 OPERATOR W. DAVIS

AMBIENT TEMP., °F 77

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 0845

HEATER ON 0910

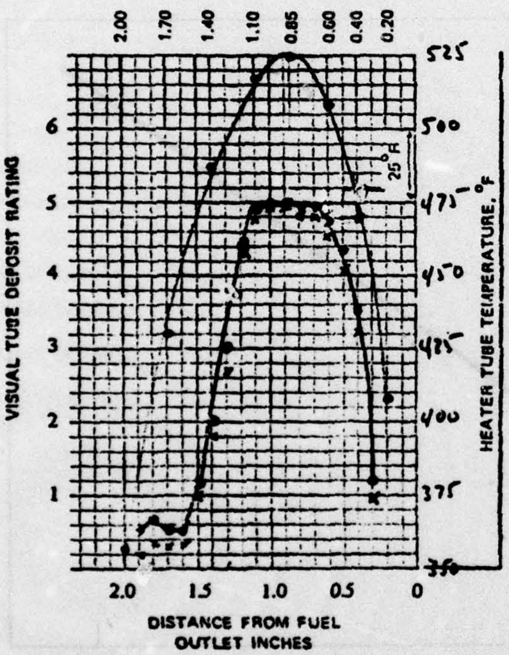
HEATER TUBE TEMPERATURE CONTROL (MAX) 525 °F

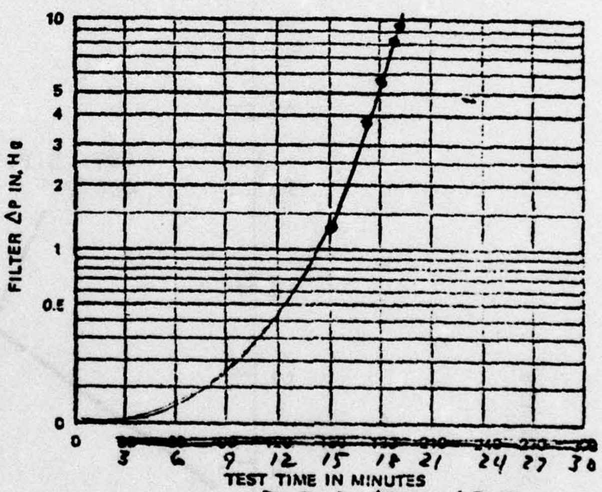
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	528
0.20	411
0.40	473
0.60	511
1.10	520
1.40	489
1.70	433
2.00	360
0.85	528

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
15	1.6
17	3.0
18	5.7
19	8.2
19.5	9.5
~~180~~	
210	
240	
270	
300	

FILTER BYPASSED AT 19.5 MIN.





40 DROPS/SEC 18.5

TEST FUEL CONSUMED 450 ml

DEPOSIT CODE: >4 Streak

0 – NO VISIBLE DEPOSITS
1 – HAZE OR DULLING, NO COLOR
2 – BARELY VISIBLE DISCOLORATION
3 – LIGHT TAN
4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = B-0

Table D-24

SYNTHOIL 202 FINAL BLEND

TUBE RATING REPEATIBILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE - 12-8-75

DATE TUBES RECEIVED 12/22 RUN # D-24

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW SPUN	NEW SPOT	USED SPUN	USED SPOT	Tube Number		VISUAL CODE	POSITION		
0.3	0.0	2.0	9.8	11.9			>2	1.5	0.1	
.4	0.0	3.7	32.2	35.3			>3	1.4	0.3	
.5	0.1	3.5	40.8	43.5			>4	1.3	0.35	
.6	0.4	3.0	45.5	47.0				STREAK		
.7	<0	2.7	48.0	48.8			>4	1.5	0.3	
.8		1.0	48.1	49.5						
.9		0.2	49.3	49.9						
1.0		0.8	49.0	49.8						
.1		0.0	47.8	49.0						
.2		<0	42.7	44.0						
.3		<0	26.8	30.0						
.4		<0	18.0	20.1						
.5	<0	1.0	9.8	11.0						
.6	0.0	0.6	3.4	5.1						
.7	<0	0.8	3.0	5.3						
.8	0.2	2.6	3.9	6.5						
.9	<0	1.0	2.9	5.1						
2.0	31.8	33.4	16.2	19.9						
MAX.			49.3							

Figure D-25

DATE 12-9-75   400 PSI   TEST NO. D-25

FUEL DESCRIPTION SYNTHOIL 202 FINAL BLEND
RIG NO. ERE-1   OPERATOR W. DAVIS
AMBIENT TEMP., °F 72

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 1040
HEATER ON 1100

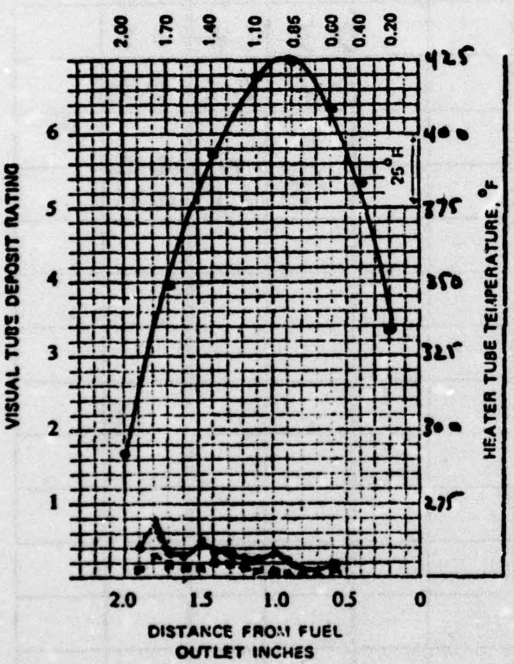
HEATER TUBE TEMPERATURE CONTROL (MAX.) 425 °F

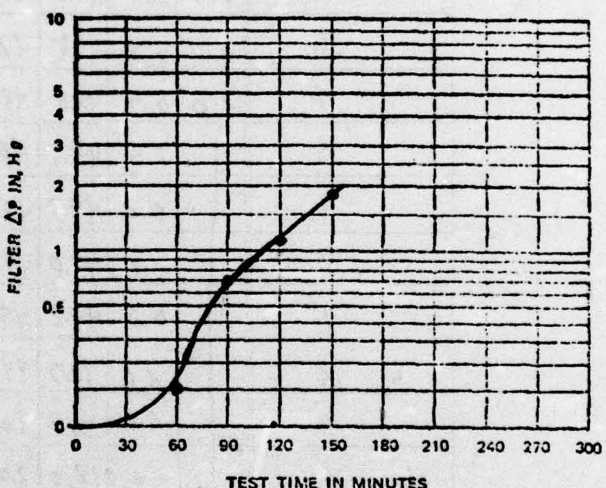
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	428
0.20	337
0.40	387
0.60	412
1.10	423
1.40	397
1.70	352
2.00	295
0.85	428

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.0
60	0.1
90	0.7
120	1.2
150	1.9
180	
210	
240	
270	
300	

FILTER BYPASSED AT —— MIN.





40 DROPS/SEC 18.4

TEST FUEL CONSUMED 450 ml

DEPOSIT CODE:

0 – NO VISIBLE DEPOSITS
1 – HAZE OR DULLING, NO COLOR
2 – BARELY VISIBLE DISCOLORATION
3 – LIGHT TAN
4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = A-0

Table D-25

SYNTHOIL 202 FINAL BLEND

TUBE RATING REPEATIBILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE - 12-9-75

DATE TUBES RECEIVED 12/72 RUN # D-25

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW		USED		Tube Number		VISUAL			
	SPUN	SPOT	SPUN	SPOT			COLOR	POSITION		
0.3	<0	<0	<0	<0			>1	1.8–	0.2	
.4	<0	<0	<0	<0						
.5	<0	0.5	<0	1.2						
.6	<0	1.8	1.0	1.8						
.7	0.0	1.3	0.5	1.0						
.8	0.0	1.0	0.7	1.0						
.9	<0	0.2	0.3	2.1						
1.0	<0	2.8	1.2	3.3						
.1	0.5	1.0	1.3	2.3						
.2	0.3	2.0	1.5	2.9						
.3	0.8	1.2	2.0	3.0						
.4	0.7	2.0	2.0	3.2						
.5	0.2	2.2	1.5	4.8						
.6	0.0	1.9	1.1	2.8						
.7	1.0	2.0	2.0	3.0						
.8	4.2	6.0	3.0	8.0						
.9	0.8	2.2	7.3	4.0						
2.0	10.0	13.2	31.0	34.0						
MAX.	0.8									

Figure D-26

DATE 12-10-75 400 PSI TEST NO. D-26

FUEL DESCRIPTION SYNTHOIL 202 FINAL BLEND

RIG NO. ERE-1 OPERATOR W. DAVIS

AMBIENT TEMP., °F 77

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 0900

HEATER ON 0920

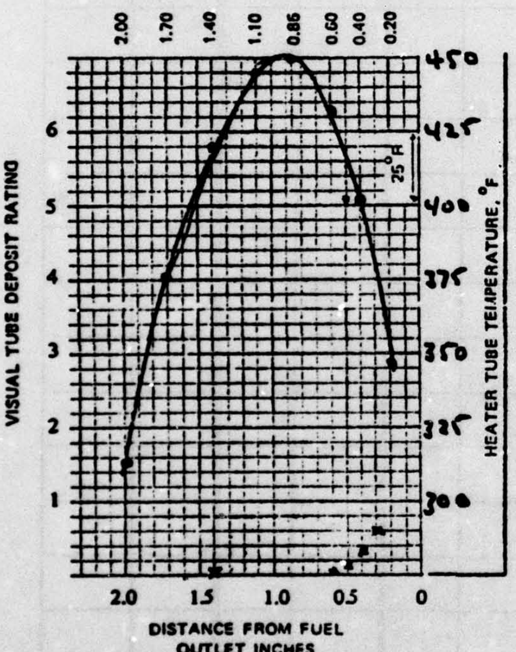
HEATER TUBE TEMPERATURE CONTROL (MAX.) 450 °F

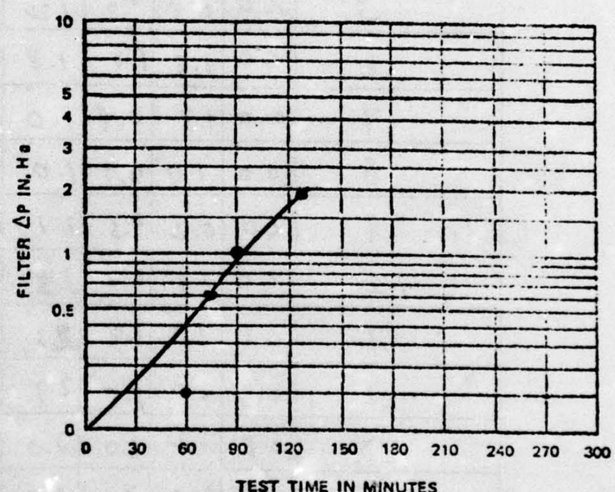
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	453
0.20	350
0.40	405
0.60	435
1.10	448
1.40	422
1.70	379
2.00	316
0.85	453

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0 0	0.0
30 30	0.0
60 60	0.1
75	0.6
90	1.0
130	1.9
150	2.3
240	
270	
300	

FILTER BYPASSED AT ——— MIN.





40 DROPS/SEC 18.2

TEST FUEL CONSUMED 440 ml

DEPOSIT CODE:

0 – NO VISIBLE DEPOSITS
1 – HAZE OR DULLING, NO COLOR
2 – BARELY VISIBLE DISCOLORATION
3 – LIGHT TAN
4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = B-0

Table D-26

SYNTHOIL 202 FINAL BLEND

TUBE RATING REPEATIBILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE - 12-10-75

DATE TUBES RECEIVED 12/72 RUN # D-26

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW		USED	Tube Number			VISUAL			
	SPUN	SPOT	SPUN	SPOT			CODE	POSITION		
0.3	4.8	7.4	6.0				+1	1.5-	0.4	
.4	2.5	4.3	3.0							
.5	0.8	4.0	1.3							
.6	0.0	1.0	0.5							
.7	<0	1.3	<0							
.8		2.2	<0							
.9		2.0								
1.0		2.7								
.1		0.0								
.2		1.0	<0							
.3		1.4	0.2							
.4		1.0	<0							
.5		1.9								
.6		1.7								
.7		0.8								
.8		<0								
.9	<0	<0								
2.0	8.2	14.3								
MAX.	0.8									

Figure D-27

DATE 12-15-75   400 PSI   TEST NO. D-27

FUEL DESCRIPTION SYNTHOIL 202 FINAL BLEND

RIG NO. ERE-1   OPERATOR W. DAVIS

AMBIENT TEMP., °F 77

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 0850

HEATER ON 0910

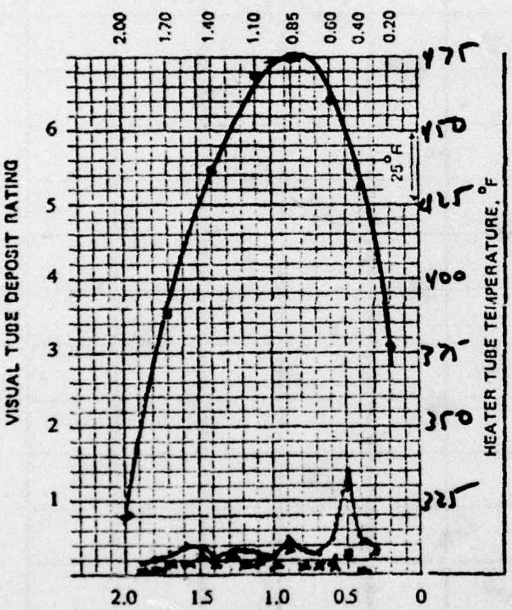
HEATER TUBE TEMPERATURE CONTROL (MAX.) 475 °F

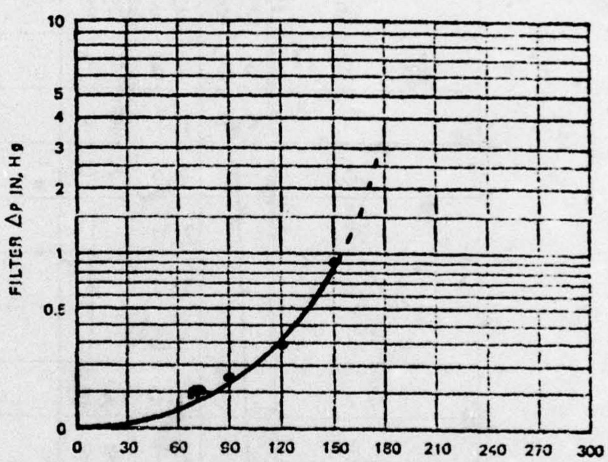
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	478
0.20	380
0.40	434
0.60	463
1.10	471
1.40	439
1.70	391
2.00	323
0.85	478

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.0
70	0.1
90	0.15
120	0.30
150	0.90
180	
210	
240	
270	
300	

FILTER BYPASSED AT ——— MIN.





40 DROPS/SEC 18.4

TEST FUEL CONSUMED 460 ml

DEPOSIT CODE:

- 0 – NO VISIBLE DEPOSITS
- 1 – HAZE OR DULLING, NO COLOR
- 2 – BARELY VISIBLE DISCOLORATION
- 3 – LIGHT TAN
- 4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = B-0

Table D-27

SYNTHOIL 202 FINAL BLEND

TUBE RATING REPEATIBILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE - 12-15-75

DATE TUBES RECEIVED 12/72 RUN # D-27

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW SPUN	NEW SPOT	USED SPUN	USED SPOT	Tube Number		VISUAL COLOR	POSITION		
0.3	1.7	5.0	3.3	3.4		1	1.6	0.3		
.4	<0	2.2	0.3	4.2						
.5	2.0	2.9	29	14.0			Scratch @ 0.5	0.4		
.6	<0	0.7	1.0	4.8						
.7	<0	0.3	1.0	2.8						
.8	<0	1.2	1.0	3.2						
.9	0.0	0.8	3.7	4.7						
1.0	<0	1.2	1.3	2.2						
.1	0.4	0.9	20	2.5						
.2	0.7	2.0	1.6	3.3						
.3	0.0	1.9	2.3	2.8						
.4	<0	2.7	1.7	1.9						
.5	1.3	2.7	2.3	3.3						
.6	0.7	2.2	1.8	4.0						
.7	0.9	2.1	1.7	3.3						
.8	<0	1.3	0.4	2.0						
.9	<0	1.0	0.2	1.4						
2.0	22.8	25.7	25.7	30.5						
MAX.			3.7							

Figure D-28

DATE 12-15-75 | 400 PSI | TEST NO. D-28

FUEL DESCRIPTION SYNTHOIL 202 FINAL BLEND
RIG NO. ERE-1 OPERATOR W. DAVIS
AMBIENT TEMP., °F 77

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 1310
HEATER ON 1330

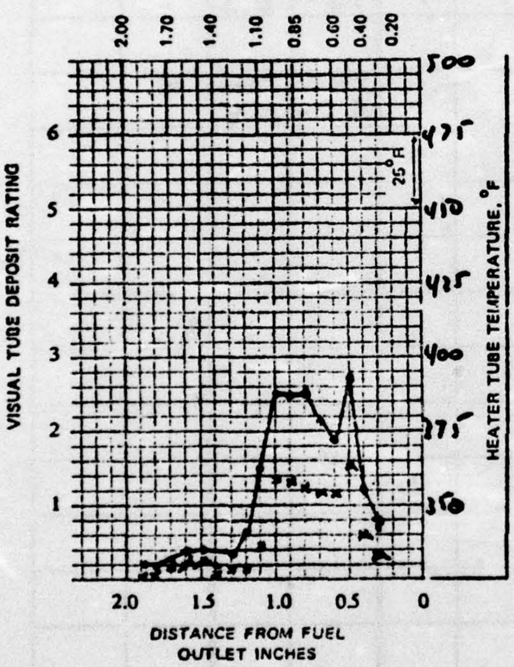
HEATER TUBE TEMPERATURE CONTROL (MAX.) 500 °F

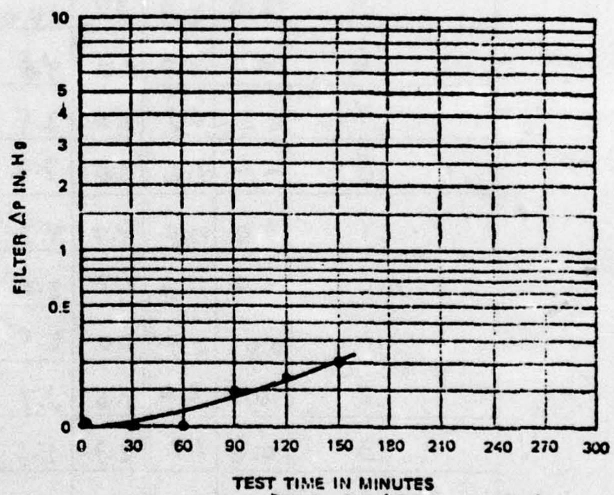
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	503
0.20	385
0.40	449
0.60	486
1.10	495
1.40	466
1.70	414
2.00	346
0.85	503

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.0
60	0.0
90	0.1
120	0.15
150	0.2
180	
210	
240	
270	
300	

FILTER BYPASSED AT ______ MIN.





40 DROPS/SEC 18.6

TEST FUEL CONSUMED 430 ml

DEPOSIT CODE: 2 Streaks >4

- 0 – NO VISIBLE DEPOSITS
- 1 – HAZE OR DULLING, NO COLOR
- 2 – BARELY VISIBLE DISCOLORATION
- 3 – LIGHT TAN
- 4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = B-3

Table D-28

SYNTHOIL 202 FINAL BLEND

TUBE RATING REPEATIBILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE - 12-15-75

DATE TUBES RECEIVED 12/72 RUN # D-28

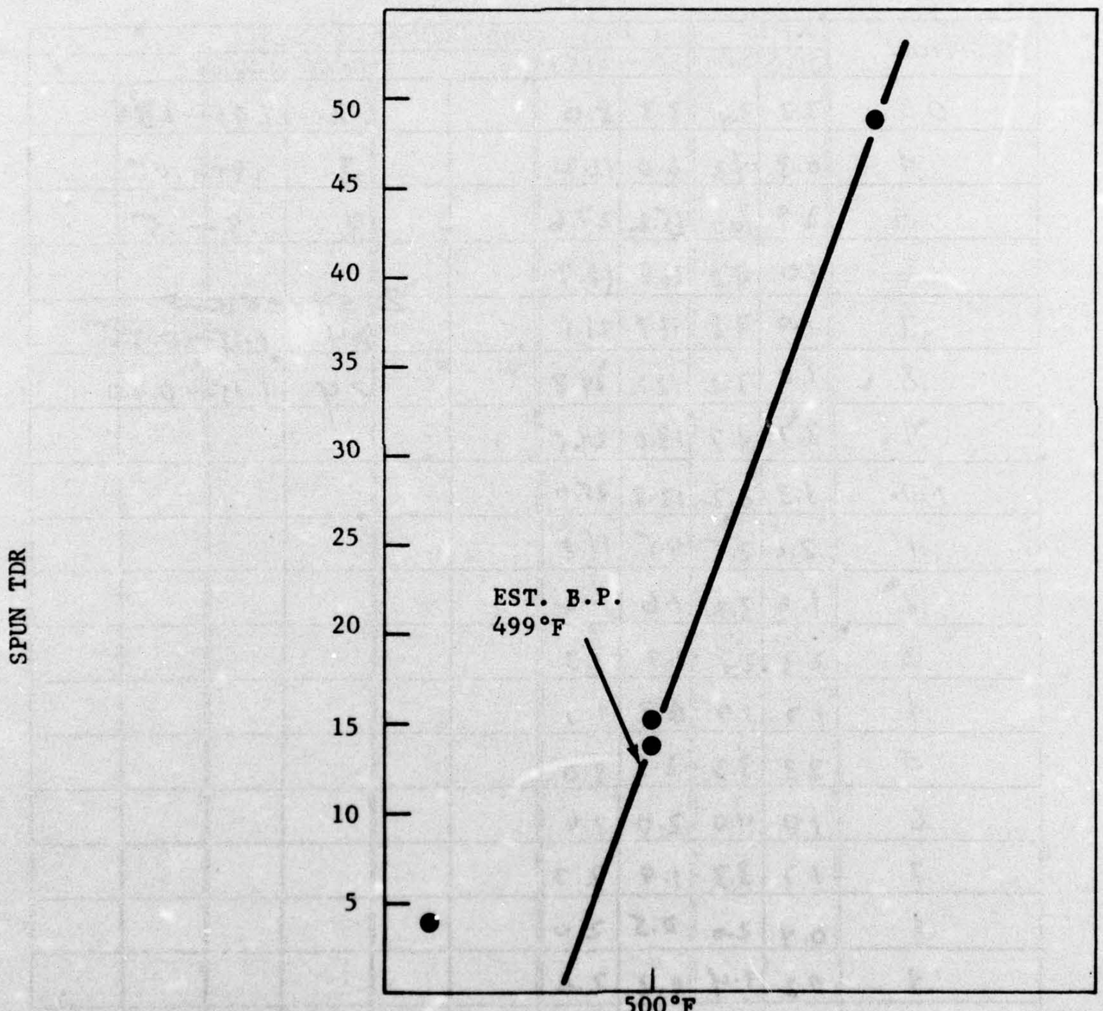
Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW		USED		Tube Number		VISUAL			
	SPUN	SPOT	SPUN	SPOT			CODE	POSITION		
0.3	3.3	3.4	3.3	8.0			>2	1.05	– .85	
.4	0.3	4.2	6.0	12.2			3	.95	– .45	
.5	2.9	14.0	15.2	27.6			4	.9	– .5	
.6	1.0	4.8	11.8	18.7						
.7	1.0	2.8	11.7	21.5		2	streaks >4	1.15	– 0.35	
.8	1.0	3.2	12.2	24.8			>4	1.15	– 0.40	
.9	3.7	4.7	13.0	24.5						
1.0	1.3	2.2	13.8	25.0						
.1	2.0	2.5	4.5	14.8						
.2	1.6	3.3	1.6	6.2						
.3	2.3	2.8	1.7	3.3						
.4	1.7	1.9	0.3	1.7						
.5	2.3	3.3	2.3	4.0						
.6	1.8	4.0	2.0	3.9						
.7	1.7	3.3	1.9	2.7						
.8	0.4	2.0	0.5	2.0						
.9	0.2	1.4	0.2	2.0						
2.0	25.7	30.5	23.8	27.0						
MAX.			13.8-15.2							

FIGURE 4-12
12-16-75

SYNTHOIL 202 FINAL BLEND

JFTOT D-24 - D-28



ALCOR JET FUEL THERMAL OXIDATION TEST

FIGURE D-29

DATE 12-16-75 400 PSI TEST NO. D-29

FUEL DESCRIPTION H-COAL 209 LIGHT FINAL BLEND

RIG NO. ERE-1 OPERATOR W. DAVIS

AMBIENT TEMP., °F 72°

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 0900

HEATER ON 0920

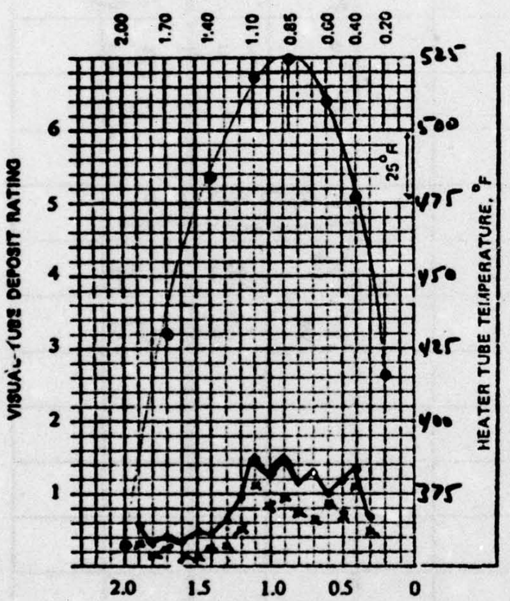
HEATER TUBE TEMPERATURE CONTROL (MAX.) 525 °F

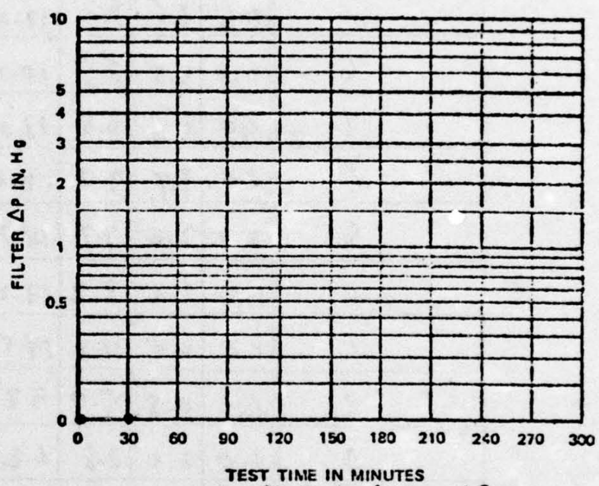
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	528
0.20	419
0.40	480
0.60	513
1.10	521
1.40	487
1.70	433
2.00	360
0.85	528

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.0
60	0.0
90	0.0
120	0.0
150	0.0
180	
210	
240	
270	
300	

FILTER BYPASSED AT —— MIN.





40 DROPS/SEC 180

TEST FUEL CONSUMED 320 ml

DEPOSIT CODE: 2 - >3 Streaks

0 – NO VISIBLE DEPOSITS
1 – HAZE OR DULLING, NO COLOR
2 – BARELY VISIBLE DISCOLORATION
3 – LIGHT TAN
4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = B - 0

Figure 7. – Suggested Data Sheet Chart

TABLE D-29
H-COAL 209 JP4 FINAL BLEND

TUBE RATING REPEATIBILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1   DATE - 12-16-75

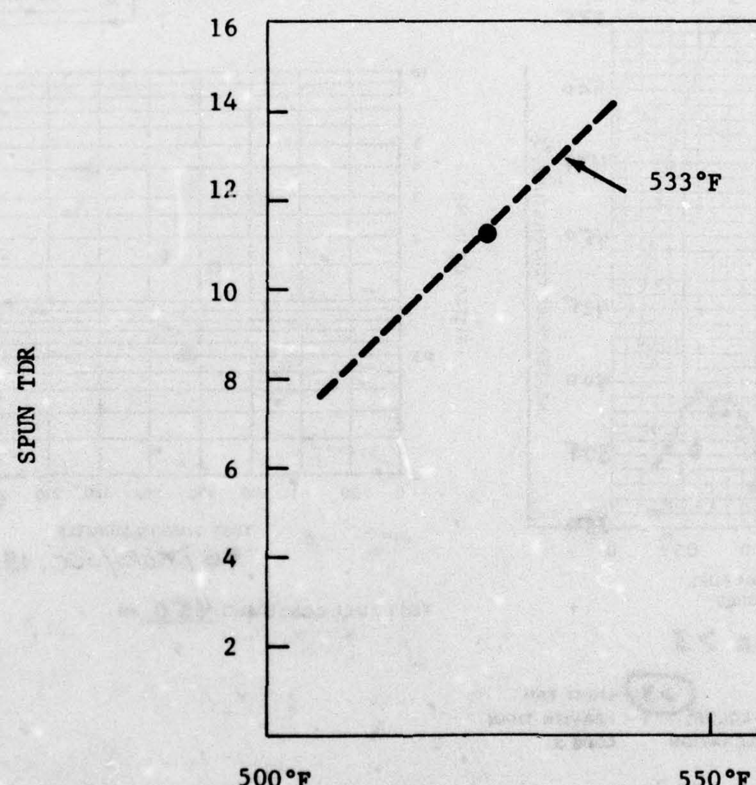
DATE TUBES RECEIVED 12/72   RUN # D-29

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW		USED		Tube Number		VISUAL			
	SPUN	SPOT	SPUN	SPOT			COLOR	POSITION		
0.3	0.8	4.0	4.7	7.0			2	1.4 + 0.2		
.4	4.2	6.2	11.0	13.7			3	1.2 + 0.3		
.5	0.6	2.5	7.0	12.0			4	1.1 + 0.4		
.6	0.8	2.5	8.5	10.0						
.7	<0	0.6	6.5	13.0			2 STREAKS			
.8	<0	3.4	7.2	12.0			>3	.95 + .45		
.9	2.2	2.0	9.7	14.7			>3	.95 + .50		
1.0	1.2	2.2	8.2	12.2						
.1	1.2	2.4	11.2	14.5						
.2	0.1	0.8	5.0	9.7						
.3	1.0	2.0	2.8	6.2						
.4	1.8	2.7	2.6	4.2						
.5	1.1	2.2	1.7	4.8						
.6	2.1	3.0	1.8	3.5						
.7	1.7	3.0	2.2	4.0						
.8	1.8	3.0	1.8	3.5						
.9	3.0	4.2	3.2	5.8						
2.0	20.0	21.8	10.5	15.0						
MAX.			11.2							

FIGURE 4-13
12-16-75

H-COAL 209 LIGHT FINAL
JFTOT D-29



ALCOR JET FUEL THERMAL OXIDATION TEST

FIGURE D-30

400 PSI

DATE 1-5-76 TEST NO. D-30

FUEL DESCRIPTION H-COAL 209 HEAVY FINAL

3 NO. ERE-1 OPERATOR W. DAVIS

AMBIENT TEMP., °F. 77

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 0920

HEATER ON 0940

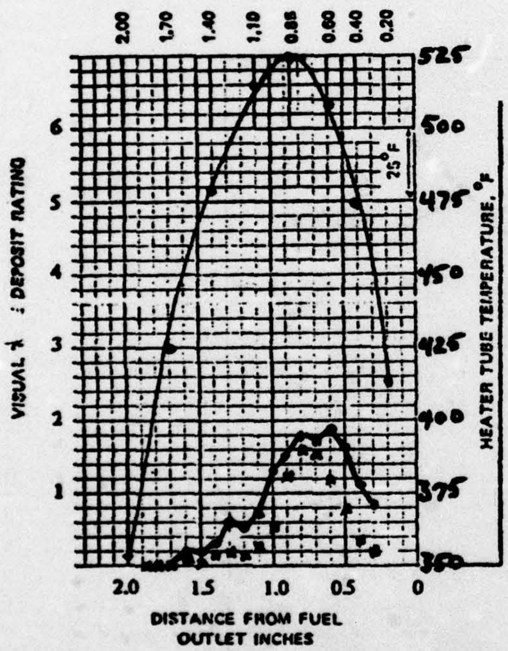
HEATER TUBE TEMPERATURE CONTROL (MAX.) 525 °F

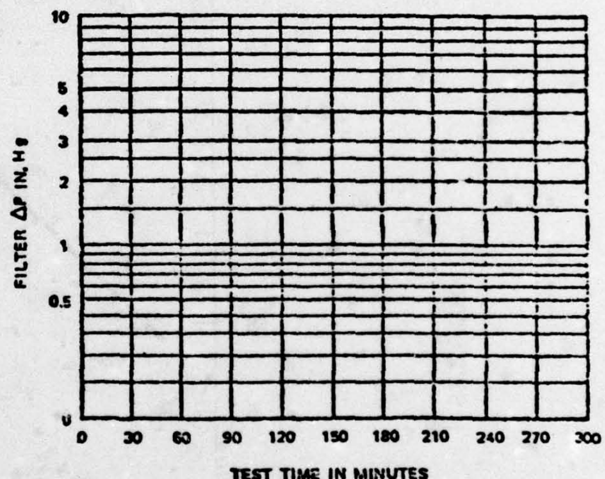
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	528
0.20	416
0.40	477
0.60	511
1.10	517
1.40	481
1.70	428
2.00	356
0.85	528

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.0
60	0.0
90	0.0
120	0.0
150	0.0
180	
210	
240	
270	
300	

FILTER BYPASSED AT ——— MIN.





40 DROPS/SEC. 18.0

TEST FUEL CONSUMED 450 ml

DEPOSIT CODE: STREAK >3

0 – NO VISIBLE DEPOSITS
1 – HAZE OR DULLING, NO COLOR
2 – BARELY VISIBLE DISCOLORATION
>3 – LIGHT TAN
4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color – B-0

Figure 7 – Suggested Data Sheet Chart

TABLE D-30
H-COAL 209 JET A FINAL BLEND

TUBE RATING REPEATIBILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE - 1-5-76

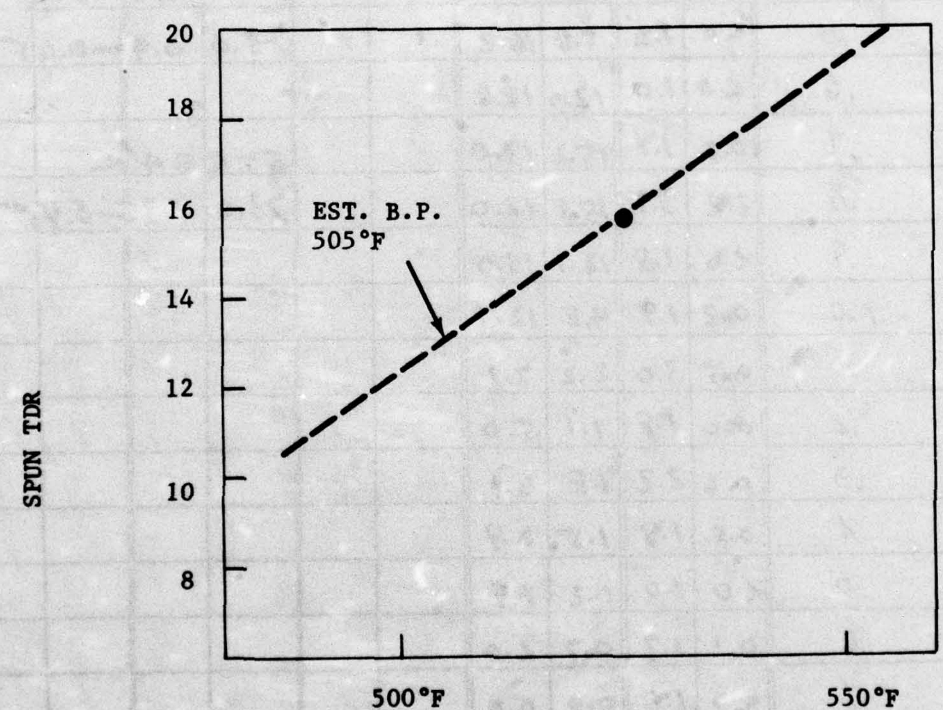
DATE TUBES RECEIVED 12/72 RUN # D-30

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW		USED		Tube Number		VISUAL			
	SPUN	SPOT	SPUN	SPOT			COLVE POSITION			
0.3	<0	<0	2.0	8.2			2.0	1.5	— 0.4	
.4	<0	<0	3.1	10.8			>2.0	0.95	— 0.6	
.5	<0	1.0	7.8	16.2			>3.0	0.9	—0.65	
.6	<0	1.0	12.0	18.8						
.7	0.7	1.1	15.2	17.0			STREAK			
.8	1.2	3.1	15.8	18.0			>3.0	1.35	—0.45	
.9	<0	1.8	12.1	15.0						
1.0	0.2	1.9	4.8	12.7						
.1	0.5	3.0	2.2	7.1						
.2	0.0	1.8	1.1	5.0						
.3	0.6	2.2	1.8	6.1						
.4	0.8	1.8	1.5	2.9						
.5	<0	1.0	0.2	1.9						
.6	0.1	1.7	0.7	2.0						
.7	<0	1.1	0.0	0.0						
.8	<0	<0	<0	<0						
.9	<0	<0	<0	<0						
2.0	18.9	23.8	17.7	24.5						
MAX.			15.8							

FIGURE 4-14
1-5-76

H-COAL 209 HEAVY FINAL
JFTOT D-30



ALCOR JET FUEL THERMAL OXIDATION TEST

FIGURE D-31

400 PSI

DATE 1-6-76 TEST NO. D-31

FUEL DESCRIPTION H-COAL 304 LIGHT FINAL

RIG NO. ERE-1 OPERATOR W. DAVIS

AMBIENT TEMP., °F 77

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 1310

HEATER ON 1330

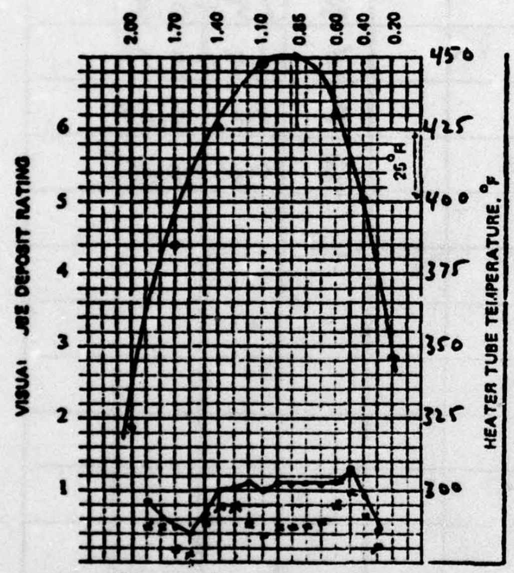
HEATER TUBE TEMPERATURE CONTROL (MAX.) 450 °F

PROFILE TEMPERATURES

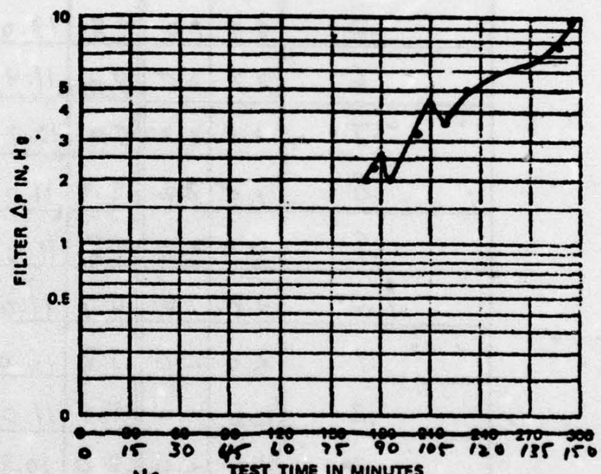
THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	453
0.20	349
0.40	404
0.60	433
1.10	451
1.40	429
1.70	388
2.00	325
0.85	453

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
87	2.0
89	2.3
90	2.5
93	2.0
100	3.2
105	4.4
110	3.7
116	5.0
143	7.6
147	9.7

FILTER BYPASSED AT 147 MIN.



DISTANCE FROM FUEL OUTLET INCHES



* 40 DROPS/SEC 18 - 31

TEST FUEL CONSUMED 300 ml

DEPOSIT CODE:

0 – NO VISIBLE DEPOSITS
1 – HAZE OR DULLING, NO COLOR
2 – BARELY VISIBLE DISCOLORATION
3 – LIGHT TAN
4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = B-0

* VARIABLE FLOW RATE DUE TO LIGHT END VAPORIZATION. BREAKPOINT IS PROBABLY HIGHER THAN INDICATED.

TABLE D-31
H-COAL 304 JP4 FINAL BLEND

TUBE RATING REPEATIBILITY AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE - 1-6-76

DATE TUBES RECEIVED 12/72 RUN # D-31

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW		USED Tube Number				VISUAL			
	SPUN	SPOT	SPUN	SPOT			CODE	POSITION		
0.3	<0	0.0	2.2	4.2			2	1.5	0.3	
.4	0.0	0.8	6.5	9.1			3	1.4	1.5	
.5	0.7	1.0	9.8	13.0			2	1.1	0.65	
.6	0.2	1.5	8.0	11.4			3	0.65	0.45	
.7	1.0	2.2	5.9	10.7						
.8	1.5	2.2	4.9	11.0						
.9	0.9	2.0	4.8	11.0						
1.0	0.8	1.4	4.7	11.0						
.1	<0	<0	3.8	10.0						
.2	<0	<0	5.5	11.0						
.3	<0	<0	8.0	10.3						
.4	0.2	2.0	7.9	10.0						
.5	2.1	3.3	5.3	6.5						
.6	<0	1.1	1.0	4.0						
.7	1.0	3.0	1.9	5.0						
.8	5.1	6.0	4.7	6.1						
.9	5.1	7.8	5.2	8.5						
2.0	28.2	32.5	25.8	29.2						
MAX.			9.8							

FIGURE 4-15
1-6-76

H-COAL 304 LIGHT FINAL
JFTOT D-31

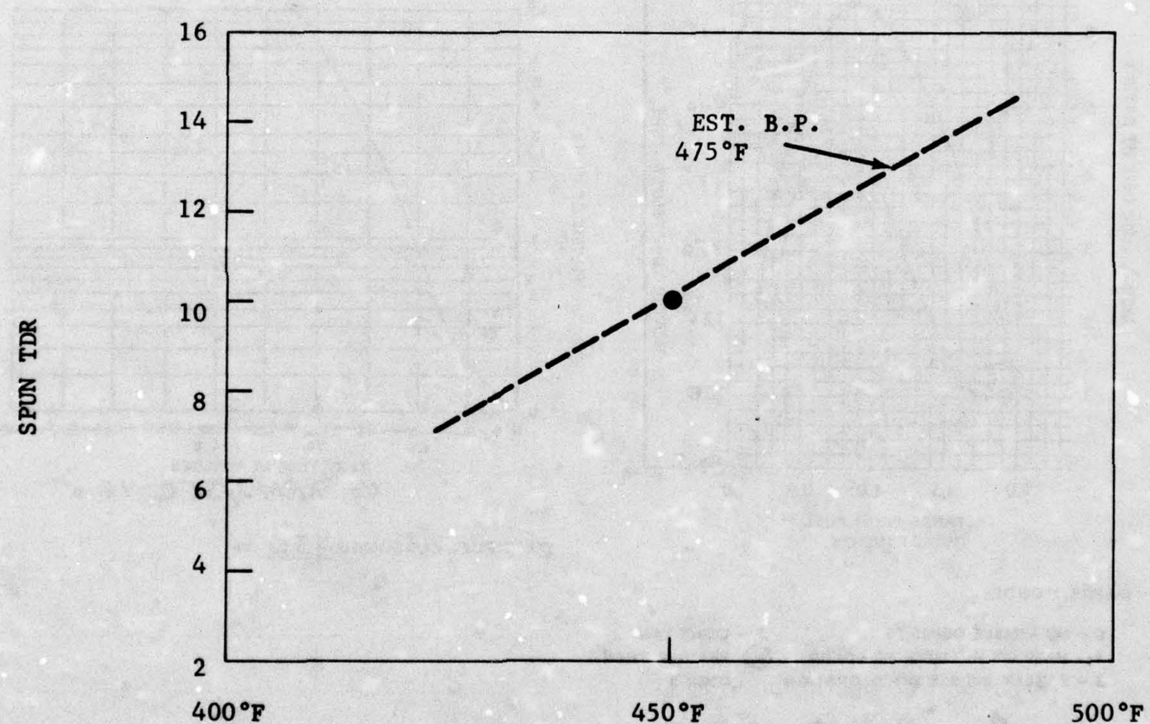


FIGURE D-32
400 PSI

DATE 1-7-76 TEST NO. D-32

FUEL DESCRIPTION H-COAL 30Y HEAVY FINAL
RIG NO. ERE-1 OPERATOR W. Davis
AMBIENT TEMP., °F 77

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 0900
HEATER ON 0930

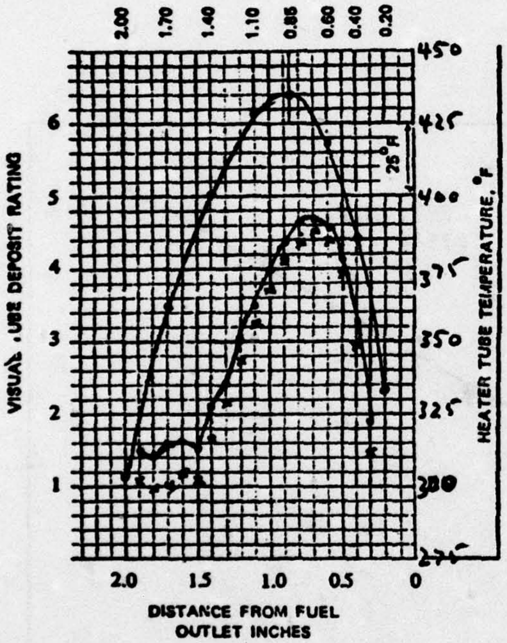
HEATER TUBE TEMPERATURE CONTROL (MAX.) 435 °F

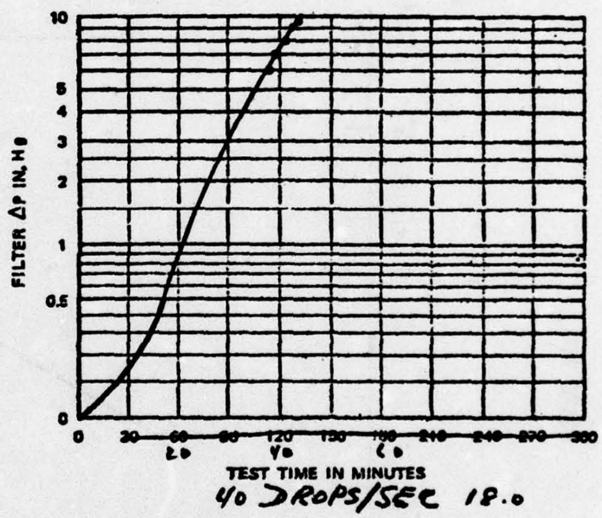
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	438
0.20	336
0.40	389
0.60	421
1.10	432
1.40	404
1.70	365
2.00	306
0.85	438

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	
37.7	6.0
39.1	7.0
41.9	8.0
42.6	9.0
44.5	9.5

FILTER BYPASSED AT 44.5 MIN.





TEST FUEL CONSUMED 430 ml

DEPOSIT CODE:

0 – NO VISIBLE DEPOSITS
1 – HAZE OR DULLING, NO COLOR
2 – BARELY VISIBLE DISCOLORATION
3 – LIGHT TAN
4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = B-1

Figure 7.– Suggested Data Sheet Chart

TABLE D-32
H-COAL 304 JET A FINAL BLEND

TUBE RATING REPEATIBILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE - 1-7-76

DATE TUBES RECEIVED 12/72 RUN # D-32

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW		USED		Tube Number		VISUAL			
	SPUN	SPOT	SPUN	SPOT			COLOR	POSITION		
0.3	<0	0.5	15.0	19.0			4+	1.6+	0.3	
.4	<0	3.0	29.5	32.5						
.5	<0	1.6	39.4	41.5			PEACOCKING			
.6	<0	5.2	44.0	45.5			4−	1.3+		
.7	<0	3.0	45.2	46.8						
.8	0.2	1.1	43.8	46.2						
.9	0.3	3.2	41.1	43.8						
1.0	<0	6.0	37.0	39.8						
.1	0.0	2.8	32.2	34.7						
.2	1.1	4.7	27.3	30.0						
.3	1.9	4.3	21.7	24.1						
.4	2.5	6.0	16.5	20.6						
.5	3.0	7.0	10.7	15.0						
.6	2.0	5.8	12.0	16.2						
.7	1.3	5.5	10.3	16.0						
.8	<0	3.8	10.0	14.2						
.9	0.7	4.0	11.0	15.2						
2.0	34.3	35.8	31.7	34.8						
MAX.	3.0		45.2							

ALCOR JET FUEL THERMAL OXIDATION TEST

FIGURE D-33
400 PSI

DATE 1-7-76 TEST NO. D-33

FUEL DESCRIPTION H-COAL 304 HEAVY FINAL
RIG NO. ERE-1 OPERATOR W. DAVIS
AMBIENT TEMP., °F 77

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 1245
HEATER ON 1305

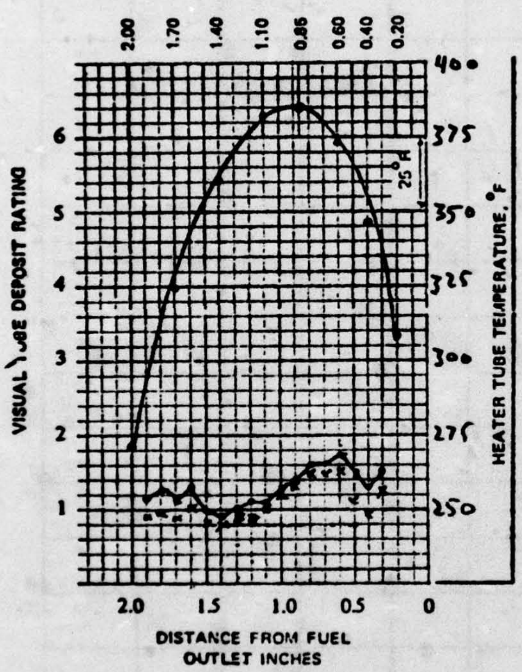
HEATER TUBE TEMPERATURE CONTROL (MAX) 385 °F

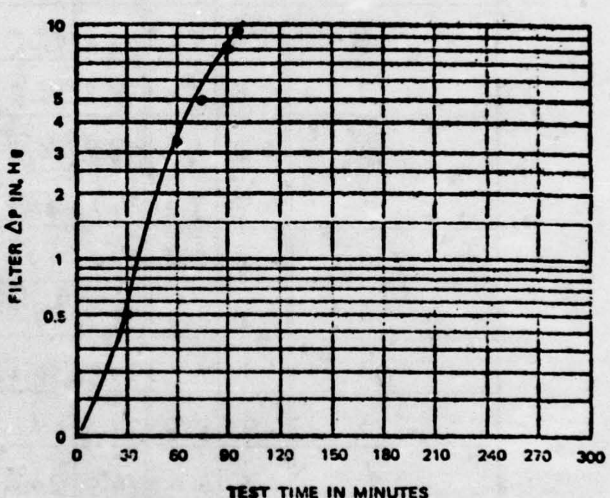
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	388
0.20	311
0.40	349
0.60	376
1.10	385
1.40	363
1.70	327
2.00	274
0.85	388

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.5
60	3.3
75	5.0
90	8.0
98	9.5

FILTER BYPASSED AT 98 MIN.





40 DROPS/SEC 20.0

TEST FUEL CONSUMED 430 ml

DEPOSIT CODE:

0 – NO VISIBLE DEPOSITS
1 – HAZE OR DULLING, NO COLOR
2 – BARELY VISIBLE DISCOLORATION
<3 – LIGHT TAN
4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = B-1

TABLE D-33
H-COAL 304 JET A FINAL BLEND

TUBE RATING REPEATIBILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE 1-7-76

DATE TUBES RECEIVED 12/72 RUN # D-33

Tube Deposit Ratings, ALCOR Mark 8

Position	NEW SPUN	NEW SPOT	USED SPUN	USED SPOT	Tube Number		VISUAL CODE	VISUAL POSITION		
0.3	3.2	4.3	12.5	15.7			2	[illegible].8 - 0.3		
.4	0.5	2.3	9.6	13.0			<3	1.3 - 0.6		
.5	0.0	1.6	11.5	15.2						
.6	<0	<0	14.9	17.4						
.7	1.7	3.2	14.3	16.2						
.8	1.9	2.6	14.5	16.0						
.9	1.0	2.0	13.1	14.0						
1.0	1.0	2.2	12.1	12.8						
.1	<0	0.0	10.0	10.8						
.2	<0	0.2	9.2	11.3						
.3	0.0	1.0	9.2	10.0						
.4	<0	1.0	8.0	8.8						
.5	<0	1.5	8.2	9.8						
.6	0.3	2.2	10.2	13.0						
.7	<0	1.9	8.8	11.1						
.8	1.8	3.0	9.8	12.7						
.9	3.1	6.0	9.2	11.8						
2.0	35.1	37.8	27.0	28.8						
MAX.	1.9		14.9							

FIGURE 4-16
1-7-76

H-COAL 304 HEAVY FINAL
JFTOT D-32, D-33

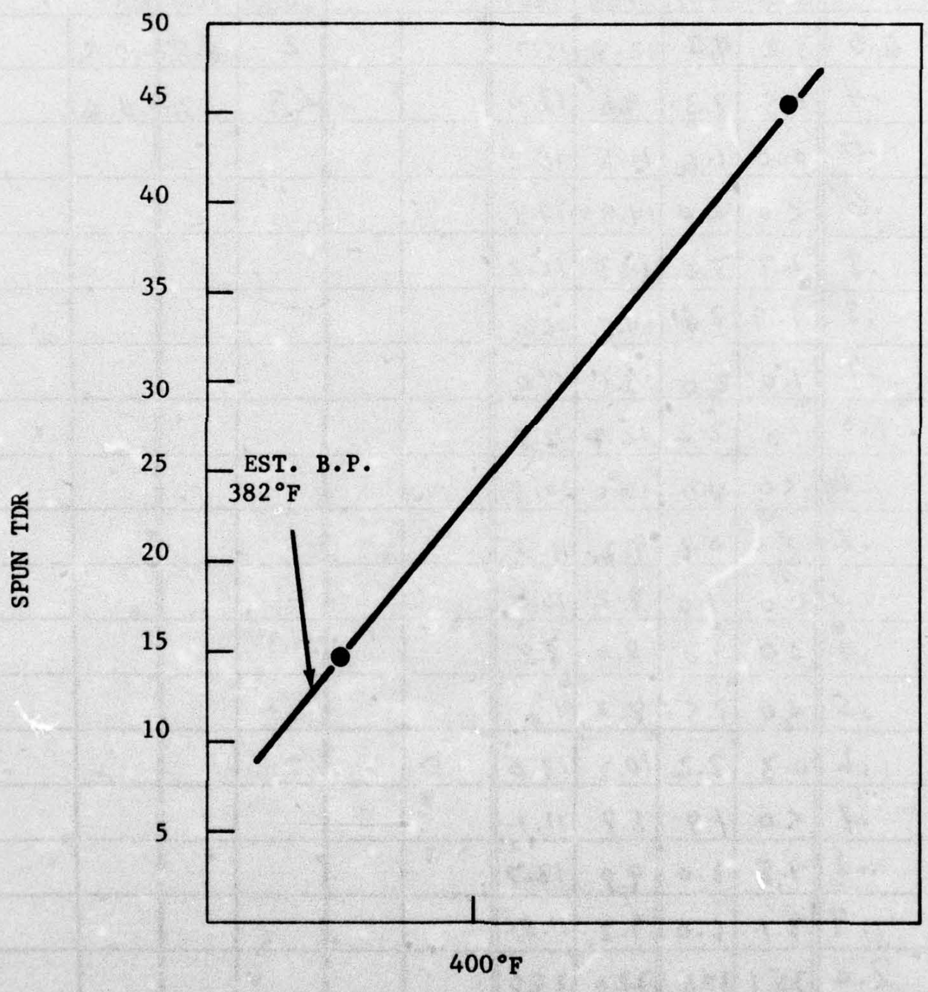


FIGURE D-34

ALCOR JET FUEL THERMAL OXIDATION TEST

DATE 3-15-76　　　　400 PSI　　　　TEST NO. D-34

FUEL DESCRIPTION GARRETT 415 FINAL BLEND
RIG NO. ERE-1　OPERATOR W. DAVIS
AMBIENT TEMP., °F 77

TEMPERATURE CALIBRATION
TRUE MELTING POINT 449 °F
INDICATED MP 452 °F
ERROR +2 °F

CLOCK TIME
FUEL AERATED 0940
HEATER ON 1015

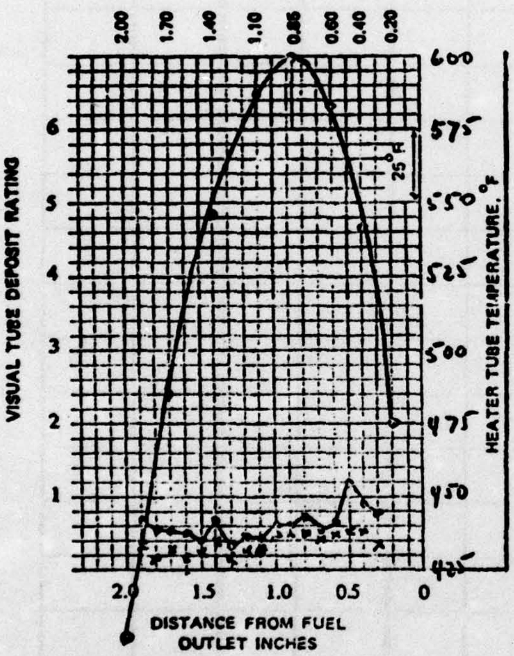
HEATER TUBE TEMPERATURE CONTROL (MAX.) 600 °F

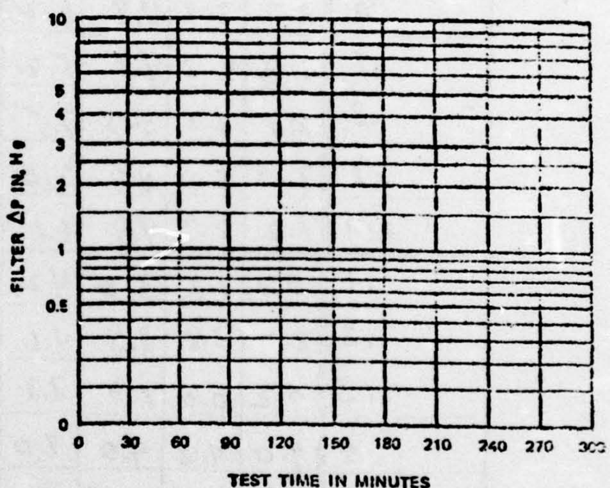
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	603
0.20	478
0.40	545
0.60	586
1.10	590
1.40	549
1.70	488
2.00	403
0.85	603

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.0
60	0.0
90	0.0
120	0.0
150	0.0
180	
210	
240	
270	
300	

FILTER BYPASSED AT — MIN.





40 DROPS/SEC 18

TEST FUEL CONSUMED 455 ml

DEPOSIT CODE:

- 0 – NO VISIBLE DEPOSITS
- 1 – HAZE OR DULLING, NO COLOR
- 2 – BARELY VISIBLE DISCOLORATION
- 3 – LIGHT TAN
- 4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = B-0

TABLE D-34

GARRETT 415 JET A FINAL BLEND

TUBE RATING REPEATABILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE 3-15-76

DATE TUBES RECEIVED 12-72 RUN # D-34

Tube Deposit Ratings, ALCOR Mark 8

	NEW		USED		Tube Number		VISUAL			
POSITION	SPUN	SPOT	SPUN	SPOT			CODE	POSITION		
0.3	5.7	5.3	6.9	8.0			< 2	0.3 - 1.0		
.4	3.9	6.0	5.5	9.2						
.5	3.3	4.2	5.5	12.0						
.6	2.7	3.1	4.8	6.2						
.7	1.8	3.2	4.2	5.2						
.8	2.1	4.1	5.0	7.5						
.9	2.0	3.0	4.9	6.0						
1.0	1.8	2.9	4.9	6.1						
.1	0.8	1.8	3.0	4.2						
.2	2.1	3.8	3.8	4.6						
.3	0.2	0.0	1.9	3.3						
.4	4.0	4.8	4.0	7.0						
.5	1.9	2.5	2.5	4.0						
.6	2.0	2.0	1.9	5.1						
.7	3.2	3.4	2.7	5.3						
.8	2.8	3.9	1.9	5.8						
.9	5.0	6.1	3.8	6.8						
2.0	15.4	19.7	8.5	12.2						
MAX.	4.0	4.8	5.0							

FIGURE D-35

ALCOR JET FUEL THERMAL OXIDATION TEST

DATE 3-15-76   400 PSI   TEST NO. D-35

FUEL DESCRIPTION Garrett 415 Final Blend

RIG NO. ERE-1   OPERATOR W.DAVIS

AMBIENT TEMP., °F 77

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 1340

HEATER ON 1400

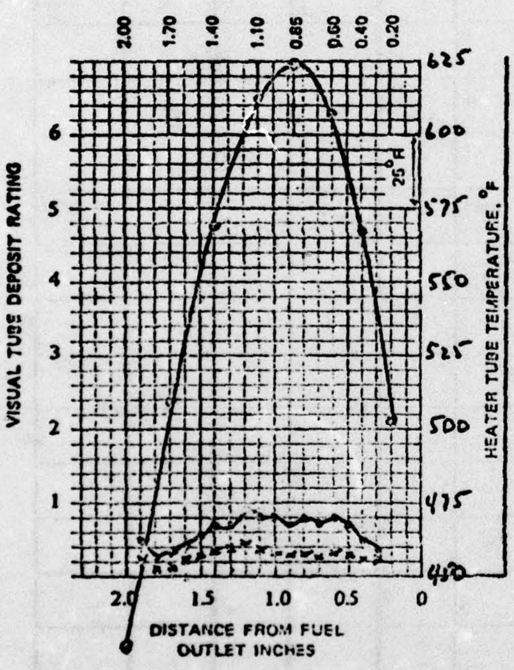
HEATER TUBE TEMPERATURE CONTROL (MAX.) 625 °F

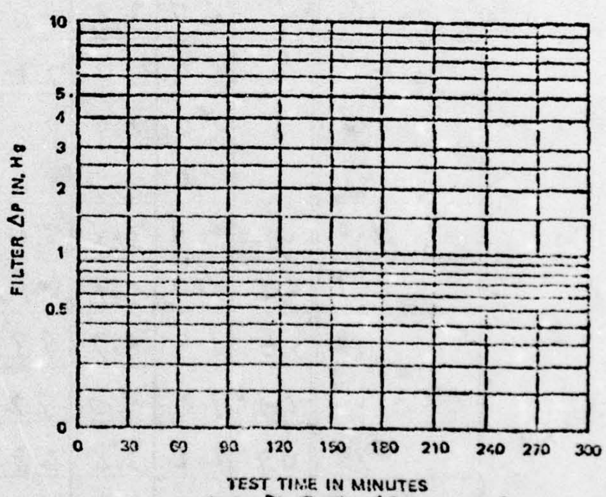
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	628
0.20	506
0.40	570
0.60	610
1.10	615
1.40	572
1.70	513
2.00	427
0.85	628

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.0
60	0.0
90	0.0
120	0.0
150	0.0
180	
210	
240	
270	
300	

FILTER BYPASSED AT — MIN.





40 DROPS/SEC 18

TEST FUEL CONSUMED 455 ml

DEPOSIT CODE:

- 0 – NO VISIBLE DEPOSITS
- 1 – HAZE OR DULLING, NO COLOR
- 2 – BARELY VISIBLE DISCOLORATION
- 3 – LIGHT TAN
- 4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = B-0

TABLE D-35

GARRETT 415 JET A FINAL BLEND

TUBE RATING REPEATIBILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE 3-15-76

DATE TUBES RECEIVED 12/72 RUN # D-35

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW		USED		Tube Number		VISUAL			
	SPUN	SPOT	SPUN	SPOT			CODE	POSITION		
0.3	<0	<0	1.2	3.9			2	0.4-	1.5	
.4		<0	1.3	4.8						
.5		<0	2.7	7.0						
.6		<0	3.3	8.0						
.7		<0	2.4	7.1						
.8		<0	2.9	8.0						
.9		<0	2.7	7.0						
1.0		<0	3.5	8.0						
.1	<0	<0	3.9	8.1						
.2	0.0	1.0	4.7	9.3						
.3	0.5	1.0	4.0	7.2						
.4	0.9	2.2	3.8	6.8						
.5	0.6	2.2	2.7	5.8						
.6	0.5	1.5	2.2	4.1						
.7	0.0	1.0	1.2	3.6						
.8	0.2	1.4	1.1	2.4						
.9	1.8	2.0	2.7	5.0						
2.0	30.8	32.8	14.8	21.6						
MAX.										

FIGURE 4-17
3-15-76

GARRETT 415 FINAL BLEND
JFTOT D-34, D-35

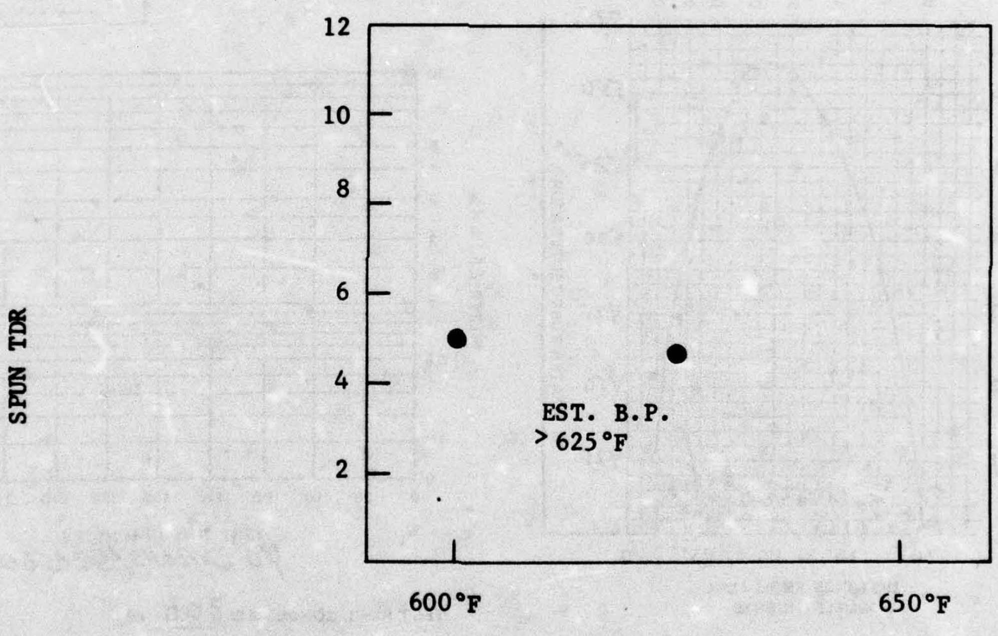


FIGURE D-36

ALCOR JET FUEL THERMAL OXIDATION TEST

DATE 3-16-76   400 PSI   TEST NO. D-36

FUEL DESCRIPTION SYNTHOIL 416 FINAL BLEN

RIG NO. ERE-1   OPERATOR W. DAVIS

AMBIENT TEMP., °F 77

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 0905

HEATER ON 0930

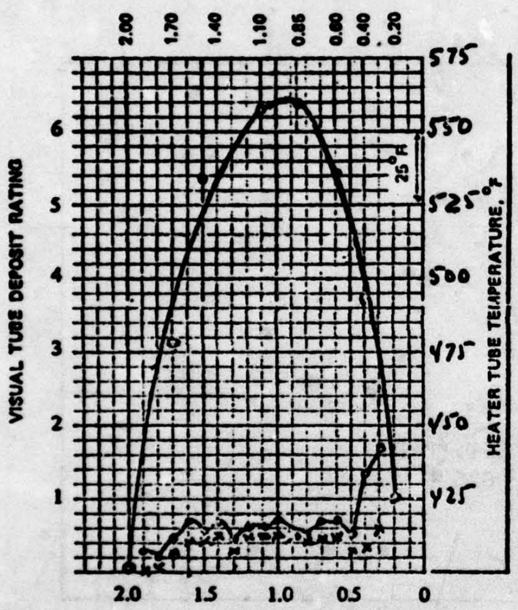
HEATER TUBE TEMPERATURE CONTROL (MAX.) 560 °F

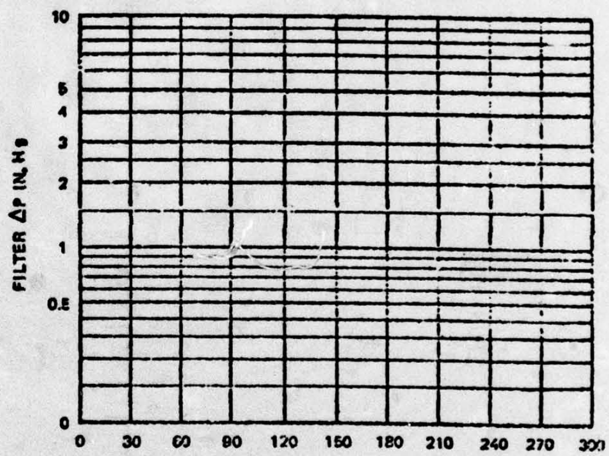
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	563
0.20	428
0.40	496
0.60	539
1.10	561
1.40	537
1.70	481
2.00	404
0.85	563

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.0
60	0.0
90	0.0
120	0.0
150	0.0
180	
210	
240	
270	
300	

FILTER BYPASSED AT — MIN.





40 DROPS/SEC 20.2

TEST FUEL CONSUMED 300 ml

DEPOSIT CODE:

0 – NO VISIBLE DEPOSITS
1 – HAZE OR DULLING, NO COLOR
2 – BARELY VISIBLE DISCOLORATION
3 – LIGHT TAN
4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = B-0

TEST IS INCONCLUSIVE DUE TO FUEL VAPORIZATION AT 400 PSI/560°F

TABLE D-36

SYNTHOIL 416 JET A FINAL BLEND

TUBE RATING REPEATIBILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE 8-16-76

DATE TUBES RECEIVED 12/72 RUN # D-36

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW SPUN	NEW SPOT	USED SPUN	USED SPOT	Tube Number		VISUAL CODE	POSITION		
0.3	6.0	10.2	8.0	17.0			No	Visible		
.4	3.7	5.9	3.8	13.8			deposits			
.5	1.7	3.9	2.9	4.8						
.6	1.9	3.8	4.7	7.1						
.7	2.9	3.2	4.5	7.0						
.8	1.7	2.8	4.2	5.1						
.9	2.2	3.4	5.0	6.0						
1.0	2.5	4.5	5.2	7.2						
.1	2.6	2.8	5.0	6.2						
.2	1.7	3.0	4.8	6.1						
.3	1.8	1.0	3.2	4.3						
.4	4.6	3.2	4.9	6.8						
.5	2.7	4.4	4.2	5.9						
.6	3.2	4.3	4.2	6.8						
.7	2.2	2.2	2.7	4.4						
.8	0.2	0.7	0.5	2.0						
.9	0.1	0.8	0.1	2.8						
2.0	28.7	31.2	[illegible]	35.8						
MAX.										

FIGURE 4-18
3-16-76

SYNTHOIL 416 FINAL BLEND
JFTOT D-36

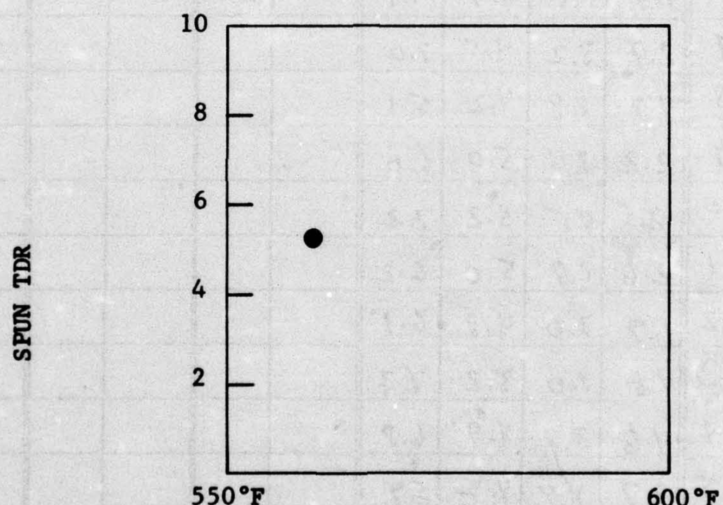


FIGURE D-37

DATE. 3-16-76 — 400 PSI — TEST NO. D-37

FUEL DESCRIPTION PARAMO 414 FINAL BLEND

RIG NO. ERE-1 OPERATOR W. DAVIS

AMBIENT TEMP., °F 77

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 1310

HEATER ON 1330

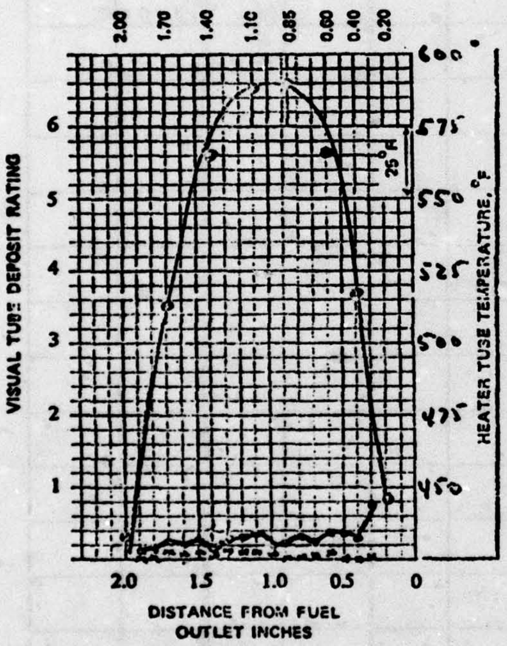
HEATER TUBE TEMPERATURE CONTROL (MAX.) 590 °F

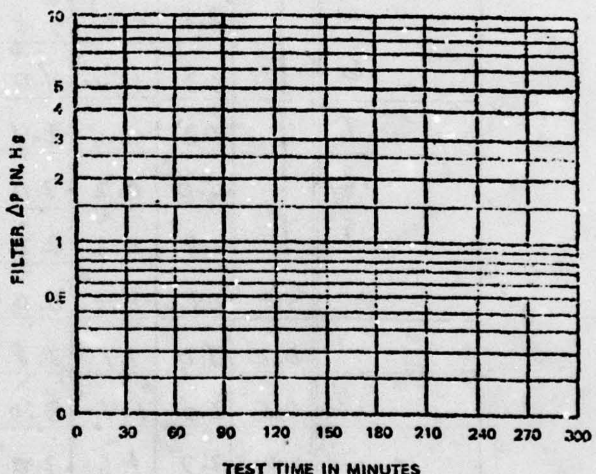
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	593
0.20	449
0.40	520
0.60	569
1.10	592
1.40	568
1.70	516
2.00	436
0.85	594

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.0
60	0.0
90	0.0
120	0.0
150	0.0
180	
210	
240	
270	
300	

FILTER BYPASSED AT —— MIN.





40 DROPS/SEC 18.2

TEST FUEL CONSUMED 200 ml

DEPOSIT CODE:

0 – NO VISIBLE DEPOSITS	3 – LIGHT TAN
1 – HAZE OR DULLING, NO COLOR	4 – HEAVIER THAN CODE 3
2 – BARELY VISIBLE DISCOLORATION	

REMARKS Prefilter Color = B-0

TEST IS INCONCLUSIVE DUE TO FUEL VAPORIZATION AT 400 PSI / 590°F

TABLE D-37

PARAHO 414 JET A FINAL BLEND

TUBE RATING REPEATIBILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE 3-16-76

DATE TUBES RECEIVED 12/72 RUN # D-37

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW SPUN	NEW SPOT	USED SPUN	USED SPOT	Tube Number		VISUAL CODE	VISUAL POSITION	
0.3	<0	3.0	0.2	7.8				NO VISIBLE	
.4	|	2.3	<0	2.8				DEPOSITS	
.5	|	2.8	<0	3.8					
.6	|	3.3	1.0	4.0					
.7	|	1.2	0.4	2.4					
.8	|	2.0	0.2	3.0					
.9	|	1.9	0.2	2.2					
1.0	<0	1.8	0.7	2.0					
.1	0.2	4.0	1.1	3.8					
.2	0.5	2.0	1.1	3.0					
.3	1.2	2.7	1.6	3.0					
.4	0.1	1.0	0.3	0.8					
.5	2.6	3.7	1.5	2.9					
.6	1.8	2.7	0.7	1.8					
.7	1.9	3.3	1.0	2.0					
.8	1.5	3.0	0.2	1.0					
.9	2.2	3.0	<0	1.1					
2.0	7.7	15.0	20.2	26.8					
MAX.			1.6	4.0					

FIGURE D-37A

ALCOR JET FUEL THERMAL OXIDATION TEST

DATE 3-22-76 — 400 PSI — TEST NO. 37-A

FUEL DESCRIPTION PARAHO 414 FINAL BLEND
RIG NO. ERE-1 OPERATOR W. DAVIS
AMBIENT TEMP., °F 78

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 0920
HEATER ON 0935

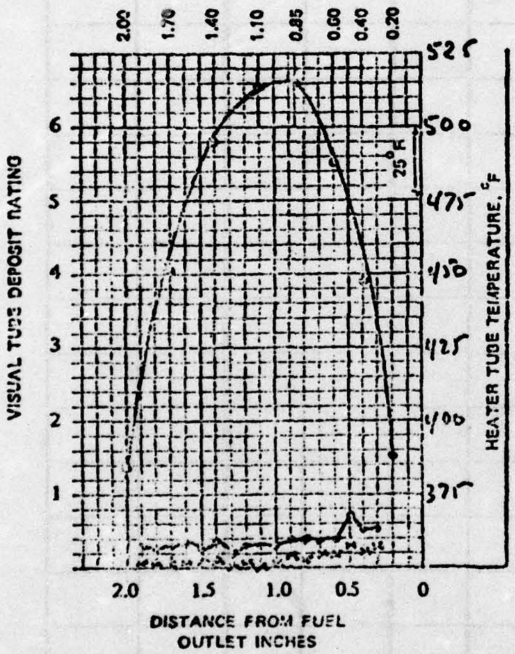
HEATER TUBE TEMPERATURE CONTROL (MAX.) 515 °F

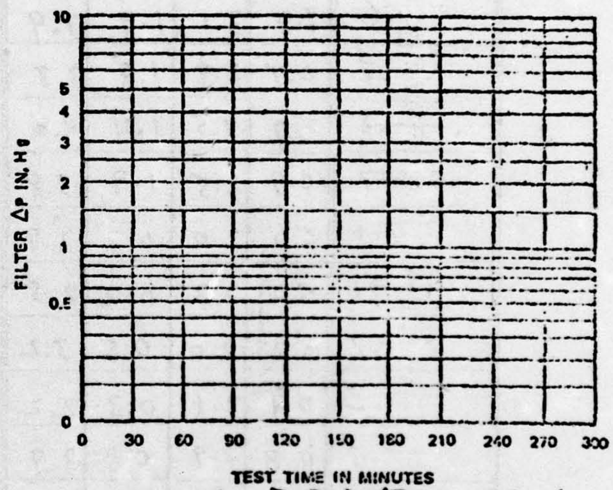
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	518
0.20	391
0.40	451
0.60	491
1.10	517
1.40	498
1.70	454
2.00	387
0.85	178

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.0
60	0.0
90	0.0
120	0.0
150	0.0
180	
210	
240	
270	
300	

FILTER BYPASSED AT — MIN.





40 DROPS/SEC 18 +

TEST FUEL CONSUMED 240 ml

DEPOSIT CODE:

0 – NO VISIBLE DEPOSITS
1 – HAZE OR DULLING, NO COLOR
2 – BARELY VISIBLE DISCOLORATION
3 – LIGHT TAN
4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = B-0

TEST NOT CONCLUSIVE DUE TO VAPORIZATION OF FUEL.

TABLE D-37A

PARAHO 414 JET A FINAL BLEND

TUBE RATING REPEATABILITY
AND REPRODUCIBILITY STUDY

LABORATORY E.RE-1 DATE 3-22-76

DATE TUBES RECEIVED RUN # D-37A

Tube Deposit Ratings, ALCOR Mark 8

	NEW		USED	Tube Number			VISUAL			
POSITION	SPUN	SPOT	SPUN	SPOT			CODE	POSITION		
0.3	2.1	4.2	3.0	5.1			1	1.4 - 0.2		
.4	2.0	5.0	2.2	5.0						
.5	2.2	6.1	3.0	7.0						
.6	1.4	3.1	1.9	3.9						
.7	0.7	2.9	1.8	3.8						
.8	0.7	3.5	1.4	4.0						
.9	0.9	2.5	1.9	3.8						
1.0	<0	2.0	0.7	2.9						
.1	<0	2.8	0.2	2.8						
.2	0.2	2.0	0.8	3.2						
.3	0.1	2.1	0.3	2.2						
.4	0.8	2.9	0.8	3.9						
.5	0.4	2.8	1.0	2.3						
.6	1.1	2.0	0.7	3.7						
.7	0.2	2.8	0.4	3.0						
.8	0.2	1.7	0.4	2.5						
.9	0.6	2.7	0.7	2.7						
2.0	25.6	30.2	27.2	30.4						
MAX.			1.9							

FIGURE 4-19
3-16-76

PARAHO 414 FINAL BLEND
JFTOT D-37, D-37A

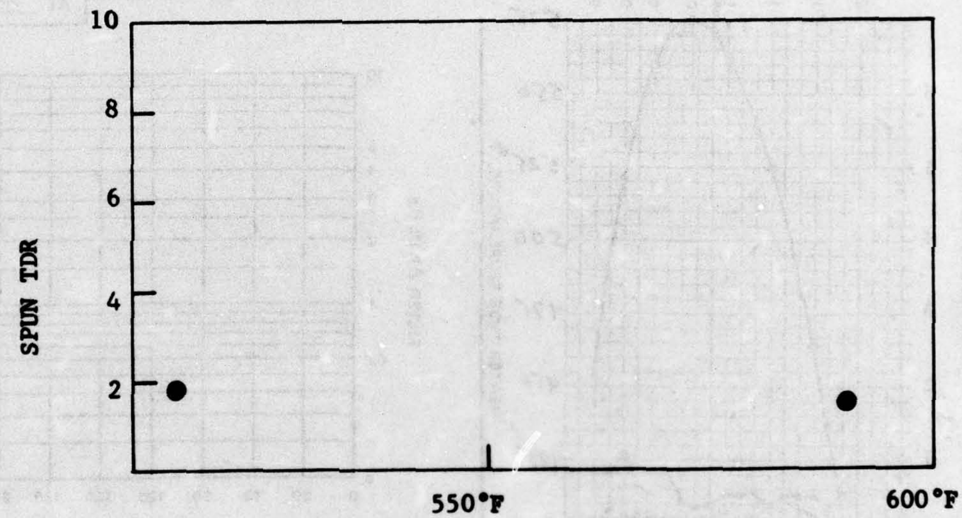


Figure 38

ALCOR JET FUEL THERMAL OXIDATION TEST

DATE 3-18-76 400 PSI TEST NO. D-38

FUEL DESCRIPTION TOSCO 410 HEAVY FINAL
RIG NO. ERE-1 OPERATOR W. DAVIS
AMBIENT TEMP., °F 74°

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 0855
HEATER ON 0925

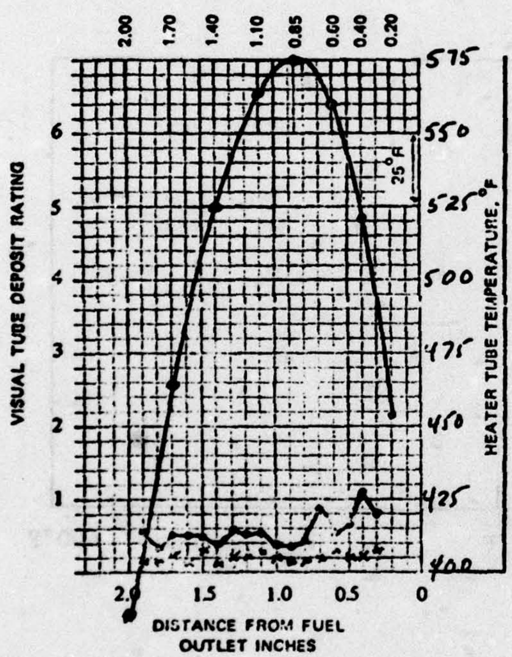
HEATER TUBE TEMPERATURE CONTROL (MAX.) 575 °F

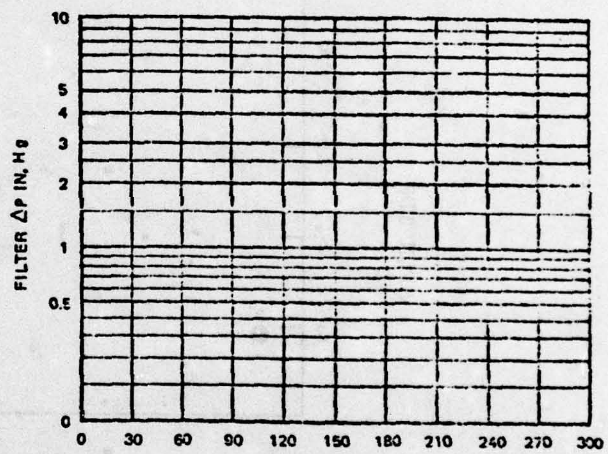
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	578
0.20	457
0.40	524
0.60	563
1.10	566
1.40	528
1.70	467
2.00	388
0.85	579

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.0
60	0.0
90	0.0
120	0.0
150	0.0
180	
210	
240	
270	
300	

FILTER BYPASSED AT ——— MIN.





40 DROPS/SEC 18.2

TEST FUEL CONSUMED 420 ml

DEPOSIT CODE:

0 – NO VISIBLE DEPOSITS
1 – HAZE OR DULLING, NO COLOR
2 – BARELY VISIBLE DISCOLORATION
3 – LIGHT TAN
4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = B-0

Slight fuel vaporization; no deposits at 575°F/400PSI.
BREAKPOINT EST. >575°F.

TABLE D-38

TOSCO 410 JET A FINAL BLEND

TUBE RATING REPEATIBILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE 3-18-76

DATE TUBES RECEIVED 12/72 RUN # D-38

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW		USED		Tube Number		VISUAL			
	SPUN	SPOT	SPUN	SPOT			CODE	POSITION		
0.3	0.2	7.8	2.7	8.1			<2	0.4 - 1.3		
.4	<0	2.8	2.0	10.7						
.5	<0	3.8	1.9	6.5						
.6	1.0	4.0	2.8	5.5						
.7	0.4	2.4	2.0	8.8						
.8	0.2	3.0	1.8	4.2						
.9	0.2	2.2	1.6	3.7						
1.0	0.7	2.0	2.0	4.0						
.1	1.1	3.8	2.7	5.7						
.2	1.1	3.0	2.0	5.0						
.3	1.6	3.0	2.1	6.0						
.4	0.3	0.8	1.2	4.0						
.5	1.5	2.9	2.8	4.6						
.6	0.7	1.8	1.4	5.0						
.7	1.0	2.0	2.2	4.8						
.8	0.2	1.0	1.8	3.6						
.9	0.2	1.1	1.8	5.8						
2.0	20.2	26.8	27.0	31.8						
MAX.			2.8							

FIGURE 4-20
3-18-76

TOSCO 410 HEAVY FINAL BLEND
JFTOT D-38

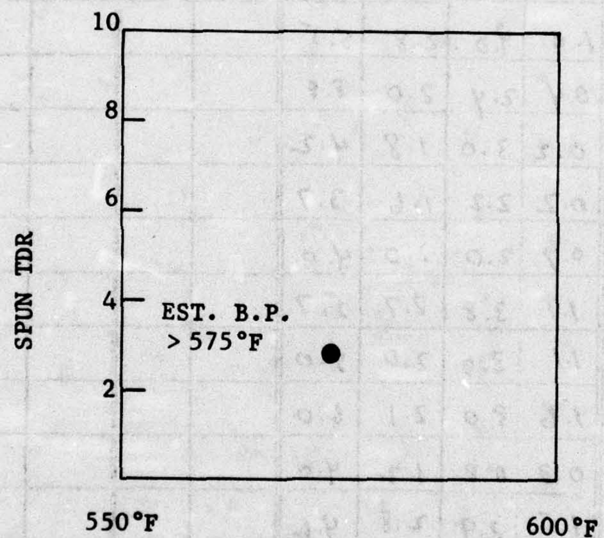


FIGURE D-39

ALCOR JET FUEL THERMAL OXIDATION TEST

DATE 3-18-76 — 400 PSI — TEST NO. D-39

FUEL DESCRIPTION GARRETT YDY HEAVY FINAL

RIG NO. ERE-1 OPERATOR W. DAVIS

AMBIENT TEMP., °F 75

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 1330

HEATER ON 1345

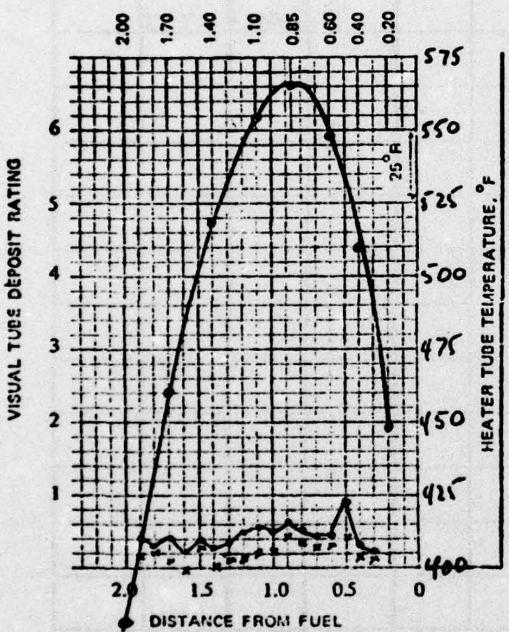
HEATER TUBE TEMPERATURE CONTROL (MAX.) 565 °F

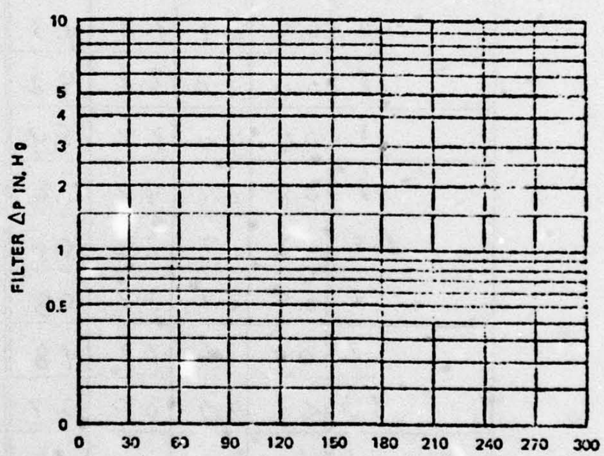
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	568
0.20	451
0.40	513
0.60	551
1.10	557
1.40	521
1.70	463
2.00	385
0.85	568

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.0
60	0.0
90	0.0
120	0.0
150	0.0
180	
210	
240	
270	
300	

FILTER BYPASSED AT — MIN.





40 DROPS/SEC 18.2

TEST FUEL CONSUMED 460 ml

DEPOSIT CODE:

- 0 – NO VISIBLE DEPOSITS
- 1 – HAZE OR DULLING, NO COLOR
- 2 – BARELY VISIBLE DISCOLORATION
- 3 – LIGHT TAN
- 4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = B-O

TABLE D-39

GARRETT 404 JET A FINAL BLEND

TUBE RATING REPEATIBILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE 3-18-76

DATE TUBES RECEIVED ____ RUN # D-39

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW SPUN	NEW SPOT	USED SPUN	USED SPOT	Tube Number		VISUAL CODE	VISUAL POSITION		
0.3	<0	1.0	1.2	2.1			0-No	Visible		
.4	0.0	1.6	1.7	3.2				Deposits		
.5	2.1	5.2	4.2	9.0						
.6	0.9	2.1	3.3	4.3						
.7	0.0	1.0	2.8	4.2						
.8	0.6	4.0	3.7	5.4						
.9	0.8	2.2	4.2	6.2						
1.0	0.2	1.7	2.2	5.0						
.1	0.9	2.0	2.2	5.8						
.2	0.4	1.6	1.7	4.8						
.3	<0	2.7	0.8	3.7						
.4	<0	<0	0.0	2.3						
.5	0.9	2.2	1.5	4.0						
.6	<0	0.8	<0	2.2						
.7	0.7	1.9	0.7	4.2						
.8	1.8	2.2	2.1	3.2						
.9	1.2	4.0	1.8	4.0						
2.0	23.0	21.8	11.2	17.3						
MAX.			4.2							

FIGURE D-40

ALCOR JET FUEL THERMAL OXIDATION TEST

DATE 3-19-76   400 PSI   TEST NO. D-40

FUEL DESCRIPTION Garrett 404 Heavy Final
RIG NO. ERE-1   OPERATOR W. Davis
AMBIENT TEMP., °F 76

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 0835
HEATER ON 0900

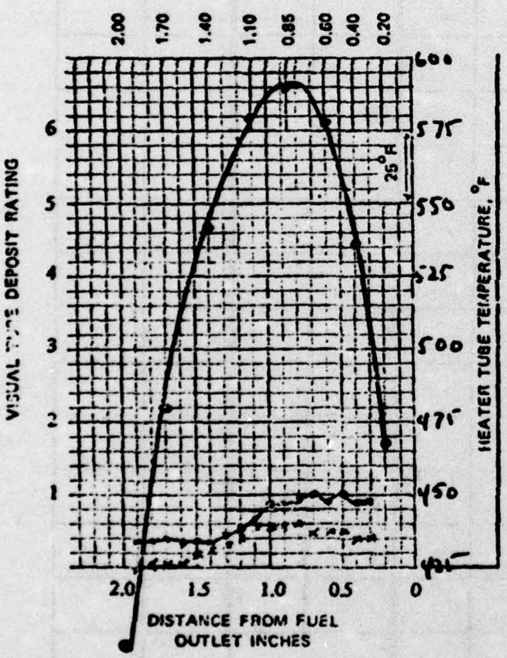
HEATER TUBE TEMPERATURE CONTROL (MAX.) 590 °F

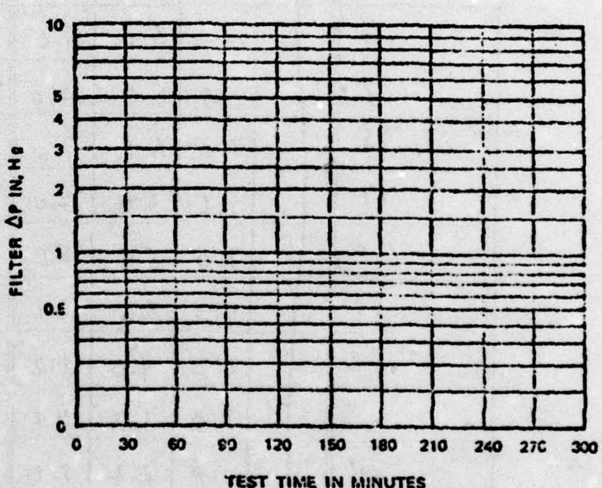
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	593
0.20	471
0.40	539
0.60	580
1.10	583
1.40	541
1.70	483
2.00	399
0.85	

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.0
60	0.0
90	0.0
120	0.0
150	0.0
180	
210	
240	
270	
300	

FILTER BYPASSED AT — MIN.





40 DROPS/SEC 18.4

TEST FUEL CONSUMED 460 ml

DEPOSIT CODE:

- 0 – NO VISIBLE DEPOSITS
- 1 – HAZE OR DULLING, NO COLOR
- 2 – BARELY VISIBLE DISCOLORATION
- 3 – LIGHT TAN
- 4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = B-0

TABLE D-40

GARRETT 404 JET A FINAL BLEND

TUBE RATING REPEATIBILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE 3-19-76

DATE TUBES RECEIVED 12/12 RUN # D-40

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW SPUN	NEW SPOT	USED SPUN	USED SPOT	Tube Number		VISUAL CODE	POSITION		
0.3	< 0	3.2	4.2	9.2			1	0.3 —	1.0	
.4		1.1	4.1	8.8						
.5		2.0	5.2	10.1						
.6		0.8	5.0	9.0						
.7		1.9	5.0	10.0						
.8		1.0	6.1	9.3						
.9		1.6	6.0	9.0						
1.0		3.0	5.4	8.8						
.1		4.0	5.6	6.1						
.2		2.2	4.0	5.2						
.3		3.0	3.0	4.1						
.4		1.0	2.2	3.0						
.5		3.0	1.8	3.7						
.6		2.2	0.2	3.6						
.7		1.8	0.2	4.0						
.8		1.0	0.2	3.8						
.9	< 0	1.7	< 0	3.7						
2.0	4.2	27.8	29.8	35.2						
MAX.			6.1							

FIGURE D-41

ALCOR JET FUEL THERMAL OXIDATION TEST

DATE 3-19-76 400 PSI TEST NO. D-41

FUEL DESCRIPTION GARRETT 404 HEAVY FINAL
RIG NO. ERE-1 OPERATOR W. DAVIS
AMBIENT TEMP., °F 78

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 1230
HEATER ON 1250

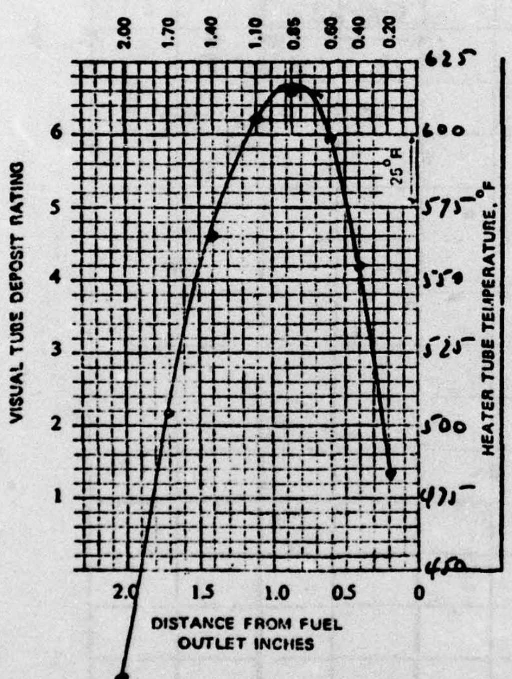
HEATER TUBE TEMPERATURE CONTROL (MAX.) 615 °F

PROFILE TEMPERATURES

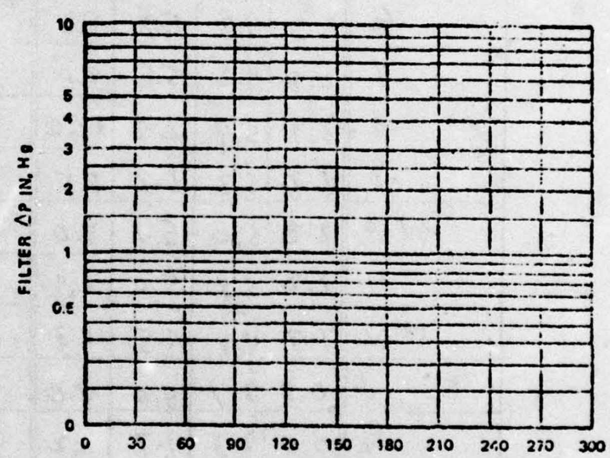
THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	618
0.20	487
0.40	558
0.60	601
1.10	609
1.40	568
1.70	507
2.00	419
0.85	618

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.0
60	0.0
90	0.0
120	0.0
150	0.0
180	
210	
240	
270	
300	

FILTER BYPASSED AT —— MIN.



DISTANCE FROM FUEL OUTLET INCHES



TEST TIME IN MINUTES

40 DROPS/SEC 18

TEST FUEL CONSUMED 460 ml

DEPOSIT CODE:

0 – NO VISIBLE DEPOSITS
1 – HAZE OR DULLING, NO COLOR
2 – BARELY VISIBLE DISCOLORATION
3 – LIGHT TAN
4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = B-4

FUEL FROM D-40 test.

TABLE D-41

GARRETT 404 JET A FINAL BLEND

TUBE RATING REPEATIBILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE 3-19-76

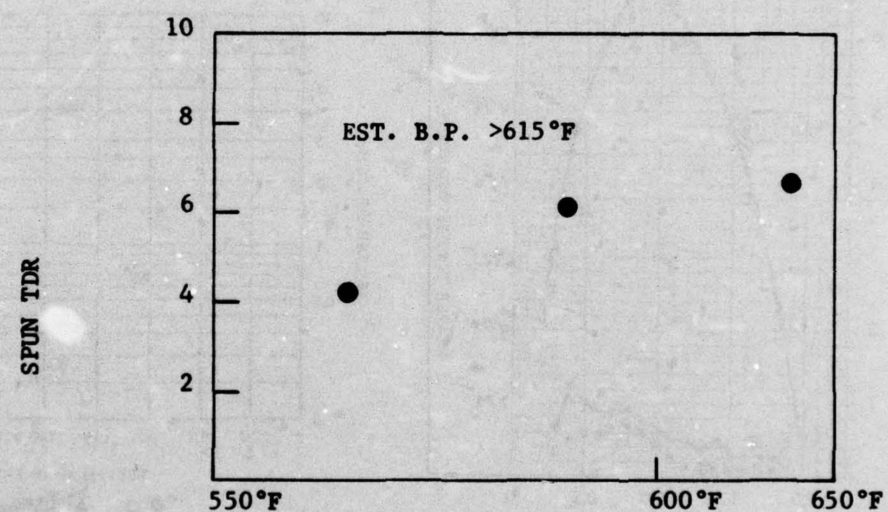
DATE TUBES RECEIVED 12/22 RUN # D-41

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW SPUN	NEW SPOT	USED SPUN	USED SPOT	Tube Number		VISUAL CODE	POSITION		
0.3	1.2	2.1	2.8	6.8			2	1.3-0.3		
.4	1.7	3.2	3.8	7.8			Streaks			
.5	4.2	9.0	6.0	10.8			3	1.2-0.8		
.6	3.3	4.3	5.8	8.6			3	0.8-0.03		
.7	2.8	4.2	5.8	8.0						
.8	3.7	5.4	6.7	13.0						
.9	4.2	6.2	6.2	8.5						
1.0	2.2	5.0	5.0	8.0						
.1	2.2	5.8	5.0	6.9						
.2	1.7	4.8	4.5	6.3						
.3	0.8	3.7	4.0	8.0						
.4	0.0	2.3	1.7	3.2						
.5	1.5	4.0	3.2	5.8						
.6	<0	2.2	1.3	5.1						
.7	0.7	4.2	2.2	7.2						
.8	2.1	3.2	2.7	6.7						
.9	1.8	4.0	2.7	6.9						
2.0	11.2	17.3	29.8	37.8						
MAX.			6.7							

FIGURE 4-21
3-19-76

GARRETT 404 HEAVY FINAL BLEND
JFTOT D-39, D-40, D-41



ALCOR JET FUEL THERMAL OXIDATION TEST

FIGURE D-42

DATE 3-23-76   400 PSI   TEST NO. D-42

FUEL DESCRIPTION H-COAL 419 FINAL BLEND
RIG NO. ERE-1   OPERATOR W. DAVIS
AMBIENT TEMP., °F 78

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 1240
HEATER ON 1300

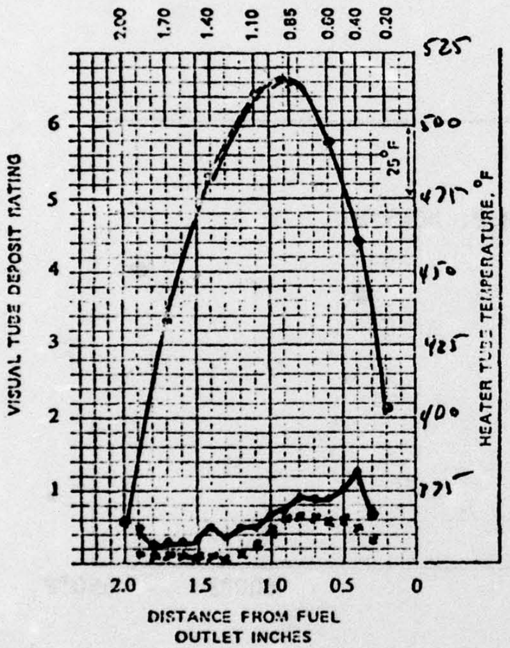
HEATER TUBE TEMPERATURE CONTROL (MAX.) 515 °F

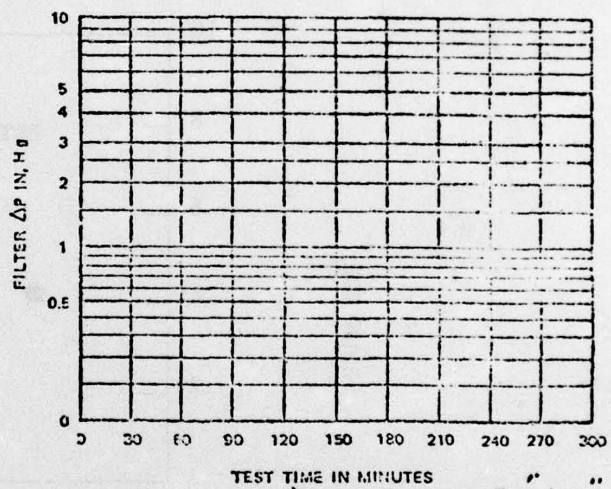
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	518
0.20	406
0.40	464
0.60	498
1.10	514
1.40	486
1.70	436
2.00	367
0.85	519

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.0
60	0.0
90	0.0
120	0.0
150	0.0
180	
210	
240	
270	
300	

FILTER BYPASSED AT [redacted] MIN.





40 DROPS/SEC. 18"-28"

TEST FUEL CONSUMED 260 ml

DEPOSIT CODE:
Streak 2-1.25—0.7

0 – NO VISIBLE DEPOSITS	3 – LIGHT TAN
1 – HAZE OR DULLING, NO COLOR	4 – HEAVIER THAN CODE 3
2 – BARELY VISIBLE DISCOLORATION	

REMARKS Prefilter Color = P-0

NOT CONCLUSIVE DUE TO VAPORIZATION OF FUEL

Figure 7.– Suggested Data Sheet Chart

TABLE D-42

H-Coal 419 Jet A Final Blend

TUBE RATING REPEATIBILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE 3-23-76

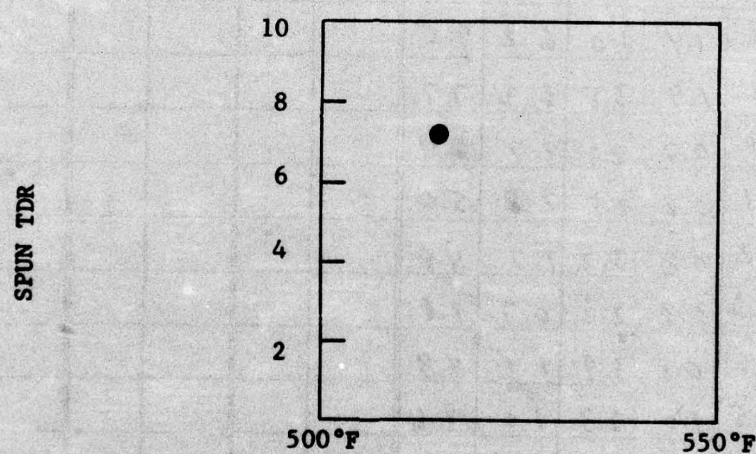
DATE TUBES RECEIVED 12/72 RUN # D-42

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW		USED Tube Number				VISUAL		
	SPUN	SPOT	SPUN	SPOT			CODE	POSITION	
0.3	3.0	5.1	3.3	7.5			2	0.9 -	0.3
.4	2.2	5.0	4.8	12.9			>2	0.8 -	0.4
.5	3.0	7.0	6.0	10.1					
.6	1.9	3.9	5.9	9.0			STREAK		
.7	1.8	3.8	6.2	9.2			2	1.25 -	0.7
.8	1.4	4.0	6.2	9.5					
.9	1.9	3.8	6.2	7.7					
1.0	0.7	2.9	4.7	6.4					
.1	0.2	2.8	2.8	5.0					
.2	0.8	3.2	1.7	4.8					
.3	1.3	2.2	0.7	3.8					
.4	0.8	3.9	1.1	4.9					
.5	1.0	2.3	1.0	3.6					
.6	0.7	3.7	0.9	3.3					
.7	0.4	3.0	0.9	3.5					
.8	0.4	2.3	0.9	2.8					
.9	0.7	2.7	1.2	5.0					
2.0	27.2	30.4	31.0	33.0					
MAX.			6.2						

FIGURE 4-22
3-23-76

H-COAL 419 FINAL BLEND
JFTOT D-42



ALCOR JET FUEL THERMAL OXIDATION TEST

DATE 3-25-76 FIGURE D-43 400 PSI TEST NO. D-43

FUEL DESCRIPTION GARRETT 404 LIGHT FINAL

RIG NO. ERE-1 OPERATOR W. DAVIS

AMBIENT TEMP., °F 79

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 1330

HEATER ON 1350

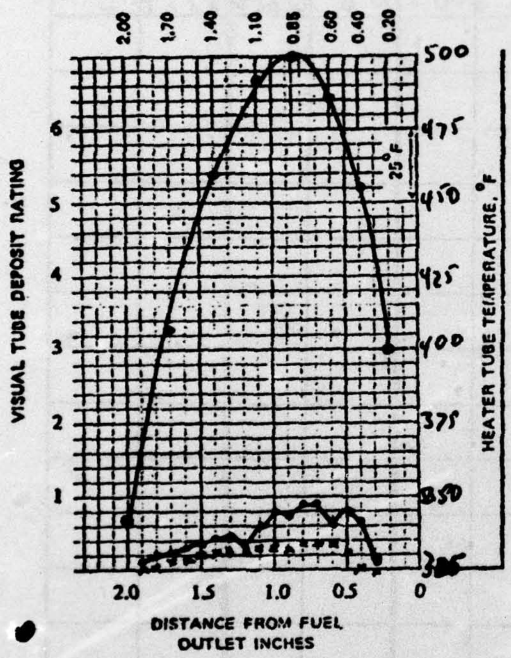
HEATER TUBE TEMPERATURE CONTROL (MAX.) 500 °F

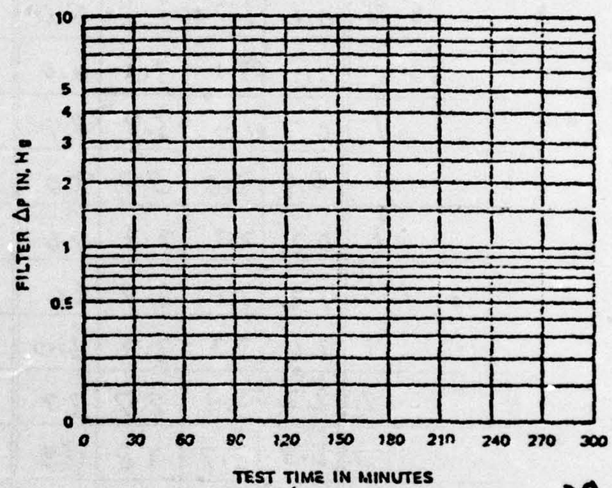
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	503
0.20	403
0.40	459
0.60	489
1.10	495
1.40	462
1.70	410
2.00	345
0.85	504

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.0
60	0.0
90	0.0
120	0.0
150	0.0
180	
210	
240	
270	
300	

FILTER BYPASSED AT — MIN.





40 DROPS/SEC, 18.2 – 28

TEST FUEL CONSUMED 360 ml

DEPOSIT CODE:

- 0 – NO VISIBLE DEPOSITS
- 1 – HAZE OR DULLING, NO COLOR
- 2 – BARELY VISIBLE DISCOLORATION
- 3 – LIGHT TAN
- 4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color = B-0

TEST IS NOT CONCLUSIVE DUE TO FUEL VAPORIZATION.

Figure 7.– Suggested Data Sheet Chart

TABLE D-43

Garrett 404 JP-4 Final Blend

TUBE RATING REPEATIBILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE 3-25-76

DATE TUBES RECEIVED 12/22 RUN # D-43

Tube Deposit Ratings, ALCOR Mark 8

	NEW		USED		Tube Number		VISUAL			
POSITION	SPUN	SPOT	SPUN	SPOT			CODE	POSITION		
0.3	<0	<0	<0	1.9		D -	NO	DEPOSIT		-
.4	<0	1.5	0.2	6.5						
.5	0.2	1.7	2.2	8.0						
.6	1.0	3.1	3.3	6.0						
.7	0.7	1.7	3.8	9.1						
.8	0.9	3.0	3.8	9.0						
.9	0.2	2.1	2.8	7.6						
1.0	1.2	3.1	3.4	8.0						
.1	2.6	3.3	3.3	6.0						
.2	2.2	5.9	2.7	3.3						
.3	2.3	3.7	2.8	4.3						
.4	2.2	4.0	2.2	4.1						
.5	1.9	4.0	2.1	3.7						
.6	1.7	3.5	1.7	3.0						
.7	1.7	3.3	1.2	2.3						
.8	0.0	1.0	0.0	2.0						
.9	0.0	0.6	0.0	1.0						
2.0	22.2	18.0	25.8	29.8						
MAX.			3.8							

FIGURE 4-23
3-25-76

GARRETT 404 LIGHT FINAL
JFTOT D-43

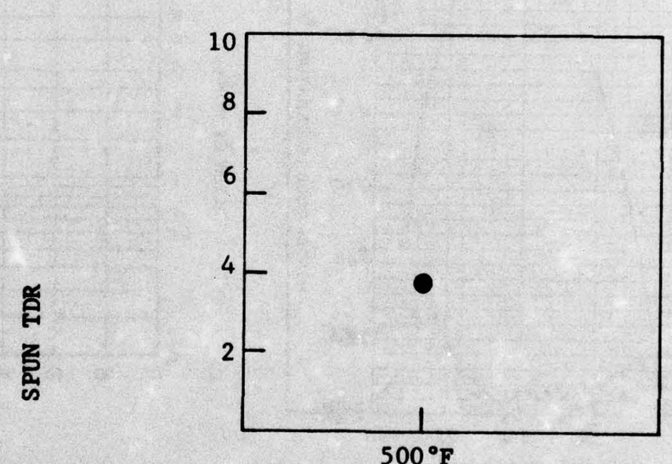


FIGURE D-44

400 PSI

DATE 3-26-76

TEST NO. D-44

FUEL DESCRIPTION TOSCO 410 LIGHT FINAL

RIG NO. ERE-1 OPERATOR W. DAVIS

AMBIENT TEMP., °F 78

TEMPERATURE CALIBRATION

TRUE MELTING POINT	449	°F
INDICATED MP	452	°F
ERROR	+3	°F

CLOCK TIME

FUEL AERATED 0850

HEATER ON 0915

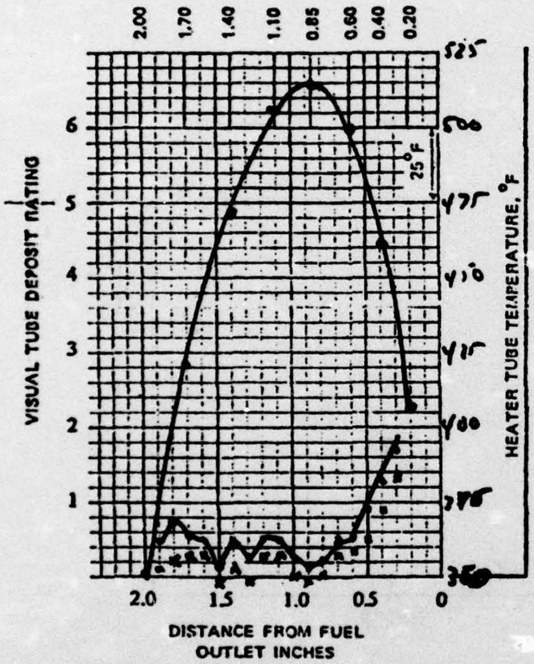
HEATER TUBE TEMPERATURE CONTROL (MAX.) 515 °F

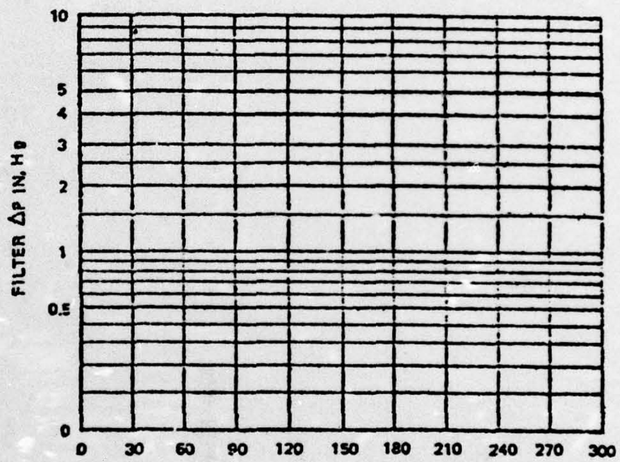
PROFILE TEMPERATURES

THERMOCOUPLE POSITION	MEASURED TEMP., °F
0.85	518
0.20	410
0.40	469
0.60	503
1.10	509
1.40	475
1.70	424
2.00	354
0.85	518

TEST TIME MINUTES	FILTER ΔP INCHES Hg
0	0.0
30	0.0
60	0.0
90	0.0
120	0.0
150	0.0
180	
210	
240	
270	
300	

FILTER BYPASSED AT — MIN.





40 DROPS/SEC, 18

TEST FUEL CONSUMED 405 ml

DEPOSIT CODE:

0 – NO VISIBLE DEPOSITS
1 – HAZE OR DULLING, NO COLOR
2 – BARELY VISIBLE DISCOLORATION
3 – LIGHT TAN
4 – HEAVIER THAN CODE 3

REMARKS Prefilter Color – 3-0

TEST IS NOT CONCLUSIVE DUE TO FUEL VAPORIZATION.

Figure 7 – Suggested Data Sheet Chart

TABLE D-44

TOSCO 410 JP-4 Final Blend

TUBE RATING REPEATIBILITY
AND REPRODUCIBILITY STUDY

LABORATORY ERE-1 DATE 3-26-76

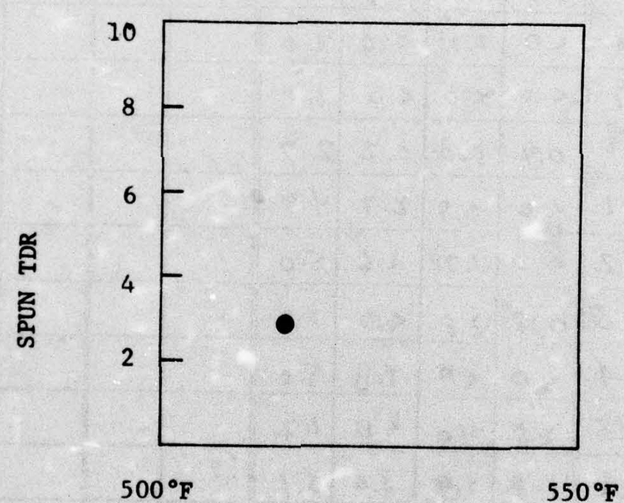
DATE TUBES RECEIVED 12/72 RUN # D-44

Tube Deposit Ratings, ALCOR Mark 8

POSITION	NEW		USED		Tube Number		VISUAL			
	SPUN	SPOT	SPUN	SPOT			CODE	POSITION		
0.3	12.5	15.8	13.0	17.0			O	— No Visible		
.4	9.2	11.3	8.8	12.8				Deposits		
.5	3.8	7.2	4.9	9.0						
.6	3.0	3.9	3.7	5.0						
.7	1.8	2.7	2.9	4.5						
.8	<0	0.2	0.0	2.0						
.9	<0	<0	<0	1.1						
1.0	0.1	3.0	0.2	2.7						
.1	<0	0.9	2.7	4.9						
.2	<0	1.7	2.6	5.0						
.3	0.8	2.8	<0	2.0						
.4	<0	<0	1.8	5.0						
.5	2.8	4.0	<0	1.2						
.6	1.8	2.9	3.0	5.1						
.7	0.0	1.8	3.2	5.7						
.8	6.5	7.8	2.2	7.5						
.9	6.2	7.2	1.0	5.0						
2.0	19.2	22.2	13.2	19.0						
MAX.			2.9							

FIGURE 4-24
3-26-76

TOSCO 410 LIGHT FINAL
JFTOT D-44



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